3. HAZARD AND ACCIDENT ANALYSIS

3.1 Introduction

The purpose of this Feasibility Study Preliminary Documented Safety Analysis (FS-PDSA) is to support remedial decisions for Operable Unit (OU) 7-13/14, which comprises the comprehensive remedial investigation and feasibility study for Waste Area Group (WAG) 7 at the Idaho National Engineering and Environmental Laboratory (INEEL). Waste Area Group 7 is the Radioactive Waste Management Complex (RWMC), which includes the Subsurface Disposal Area (SDA), a storage area for transuranic (TRU) waste and miscellaneous support operations.

Information developed throughout the remedial investigation/feasibility study process is cumulatively evaluated to assess data collection activities, assumptions, and the overall strategy for completing the remediation of WAG 7. Administrative implementability is an uncertainty associated with candidate technologies for remediating the SDA. This FS-PDSA provides the basis for evaluating the safety issues and concerns associated with the technology and its implementation in the SDA.

Hazard analysis considers the complete spectrum of accidents that may occur because of facility operations, analyzes potential accident consequences to the public and workers, estimates the likelihood of occurrence, identifies associated preventive and mitigative features, identifies safety-class and safety-significant SSCs, and identifies a selected subset of accidents designated design-basis accidents (DBAs) to be formally defined in accident analysis. The subsequent accident analysis evaluates these DBAs for comparison with evaluation guidelines to identify and assess the adequacy of safety SSCs.

3.2 Requirements

The following codes, standards, regulations, and DOE orders are specific to this subsection:

- 10 CFR 830 Subpart B, "Safety Basis Requirements"'
- DOE Order 420.1A, "Facility Safety"[2]
- DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis"[3]
- DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports"[4]
- DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses."[5]

3.3 Hazards Analysis

This section describes the hazard identification and evaluation performed for ISTD operations at the SDA. Accidents are identified and grouped (binned) in accordance with DOE-STD-3009-94. This discussion leads to the selection of a limited set of bounding accidents (DBAs) that are hrther developed in Section 3.4, "Accident Analysis." The evaluation also identifies preventive and mitigative features that must be considered in the design of ISTD.

3.3.1 Methodology

This subsection presents the methodology used to identify and characterize hazards and to perform a systematic evaluation of basic accidents.

3.3.1.1 Hazard Identification. **A** hazard is defined as a source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel, or damage to an operation or the environment. Hazards are determined without considering the likelihood or credibility of accident scenarios or consequence mitigation. Identified potential hazards are as follows:

- Existing safety documentation
- Designs and process descriptions
- U.S. Department of Energy (DOE) Occurrence Reporting and Processing System (ORPS) computer database.
- Operating history.

A what-if, checklist-type analysis was performed to identify hazards. The result of this hazard identification process is a comprehensive list of applicable hazards.

3.3.7.2 Hazard Evaluation. **A** qualitative hazard evaluation was performed for the hazards that can result in an uncontrolled release of radioactive or hazardous material and affect the off-site public, collocated workers, facility workers, or the environment.

The likelihood (anticipated, unlikely, extremely unlikely, or beyond extremely unlikely) of each hazard without controls is qualitatively estimated using the definitions in Table 3-1. No credit is taken for controls (design or administrative) that prevent or mitigate the scenario. The likelihood category is based on available data, prior studies, operating experience, and engineering judgment. Scenarios caused by human error are generally assigned to the anticipated category in the absence of controls (that is, assuming no procedures or training). Unless there are specific failure rate data or history that justify different likelihood category, scenarios caused by equipment failure are generally assigned to the anticipated category. If there is uncertainty in the likelihood category, the higher frequency category will be conservatively assumed. The consequence categories are defined in Table 3-2. The numerical consequence category guidelines for the offsite public located at the site boundary nearest to the RWMC, collocated workers assumed to be located 100 m from the release, and facility workers are based on the evaluation guidelines and criteria for the selection of safety SSCs and TSRs established in DOE-ID Order 420.D for INEEL nonreactor nuclear facilities.

A qualitative estimate for each hazard is made of the potential unmitigated consequences to the offsite public, collocated workers, facility workers, and the environment. Unmitigated means that a material's quantity, form, location, dispersibility, and interaction with available energy sources are considered, but no credit is taken for safety features (such as ventilation system and fire suppression) that could prevent or lessen a hazard. This does not require ignoring passive design features that confine radioactive or hazardous material if their failure is not postulated by the initiating scenario. The qualitative estimates of consequence category are based on developed estimates or engineering judgment. If there is uncertainty in the consequence category, then the more severe consequence category is assumed.

Table 3-1. Oualitative likelihood categories

Likelihood Category	Description	Frequency of Occurrence (annually)
Anticipated	Events that have occurred or are expected to occur during the lifetime of the facility (frequency between once in 10 and once in 100 years).	10^{-2} to 10^{-1}
Unlikely	Events that may occur but are not anticipated in the lifetime of the facility (frequency between once in 100 and once in 10,000 years).	10^{-4} to 10^{-2}
Extremely unlikely	Events that, while possible, will probably not occur in the lifetime of the facility (frequency between once in 10,000 and once in 1,000,000 years).	10^{-6} to 10^{-4}
Beyond extremely unlikely	Events that are considered too improbable to warrant hrther consideration (frequency less than once in 1,000,000 years).	$< 10^{-6}$

Table 3-2. Qualitative consequence categories.

Consequence Category	Offsite Public"	Collocated[b] Workers	Facility Workers[c]	Environment
High (H)	>25 rem[d] or >ERPG[e]-2	>100 rem[d] or >ERPG[e]-3 or >Δ10 psi[f]	>100 rem[d] or >ERPG[e]-3 or >Δ10 psi[f]	Offsite contamination or major liquid release to the groundwater.
Moderate (M)	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	25 to 100 rem[d] or ERPG[e]-2 to ERPG[e]-3	25 to 100 rem[d] or ERPG[e]-2 to ERPG[e]-3	Onsite contamination.
Low (L)	0.5 to 5 rem[d] or TLV–TWA[g,h] to ERPG-1	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	5 to 25 rem[d] or ERPG[e]-1 to ERPG[e]-2	Site area contamination outside the facility.
Negligible (N)	<0.5 rem or <TLV–TWA[g,h]	<5 rem[d] or <ERPG[e]-1	<5 rem[d] or <ERPG[e]-1	No contamination outside the facility.

a. The offsite public is a hypothetical maximally exposed individual at the nearest INEEL Site boundary.
b. The collocated worker is located outside the facility and is assumed 100 m from the release.
c. The facility worker is inside the facility (e.g., in the immediate vicinity of the release).
d. Radiation doses (rem) are TEDE.
e. Emergency Response Planning Guideline values are intended to provide estimates of concentration ranges where one might reasonably anticipate observing adverse effects, as described in the definitions of ERPG-1, ERPG-2, and ERPG-3 as a consequence of exposure to the specific substance.

The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective actions.

The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

f. Explosion overpressure is expressed as the differential pressure (A psi) of the shock wave from a detonation.
g. The TLV-TWA is the TWA concentration for a normal 8-hr workday and a 40-hr workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.
h. If a TLV-TWA or ERPG value for a specific substance has not been established, TEELs are used. The TEELs for specific chemicals are taken from *ERPGs and TEELsfor Chemicals of Concern.*[6]

ERPG	Emergency Response Planning Guide	INEEL	Idaho National Engineering and Environmental Laboratory
TEDE	total effective dose equivalent	TEEL	temporary emergency exposure limit
TLV–TWA	threshold limit value-time-weighted average		

Based on the likelihood and consequence categories, a risk bin number is assigned using the qualitative risk matrices in Figures 3-1, 3-2, and 3-3. No risk bin number is identified for environmental effects, because environmental protection is not specifically addressed by the evaluation guidelines. Only environmental controls are necessary to manage the risk to the environment. Environmental controls are determined based on a qualitative assessment of the likelihood of the scenario and the potential consequences to the environment. The risk bin numbers in the risk matrices indicate whether safety SSCs, TSRs, or safety requirements should be identified to manage the risk.

Potential scenarios initiated by natural events are evaluated in accordance with the requirements and guidelines in DOE Order 420.1A and the referenced DOE standards.

3.3.2 Hazard Analysis Results

This subsection identifies the applicable hazards and includes the hazard categorization. The safety-significant SSCs and major features for worker safety and protection of the environment are discussed. Unique and representative accidents are identified, based on the results of this hazard evaluation.

3.3.2.1 Hazard Identification

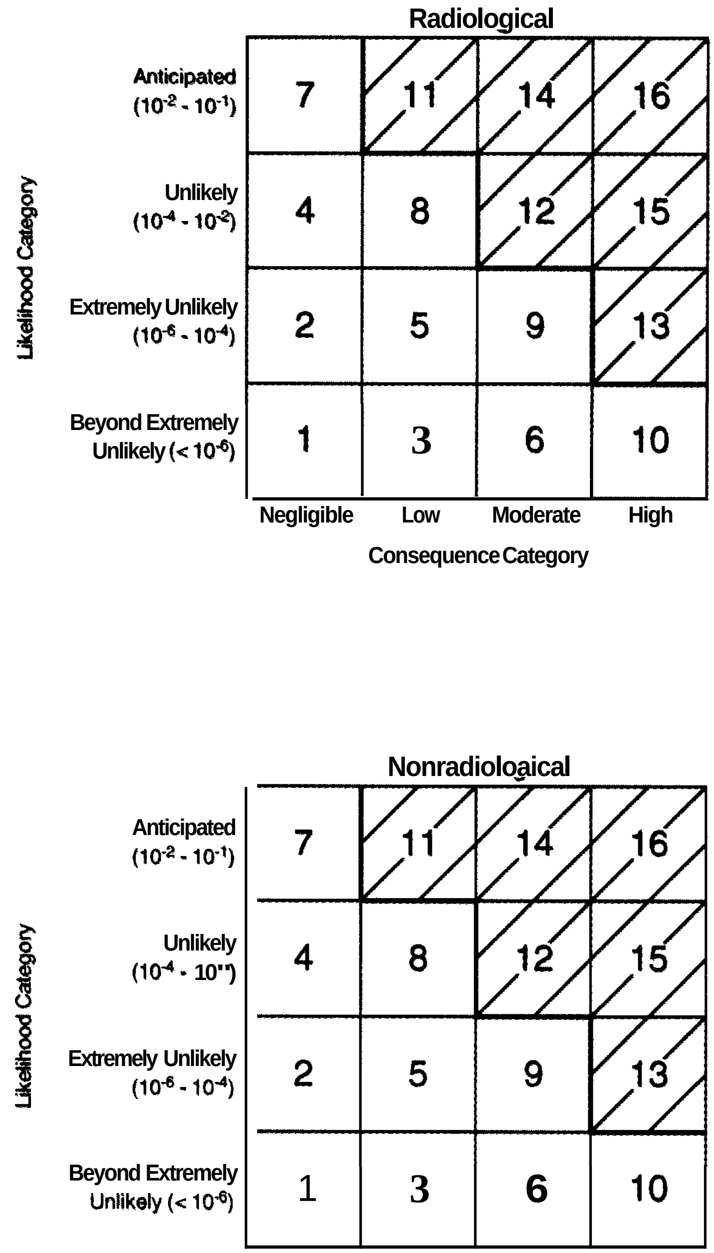
3.3.2.1.1 Applicable Hazards — Applicable occurrences from the DOE ORPS database are summarized in Table 3-3. These events suggest potential safety concerns with deflagration reactions, unexpected contamination, and failure of power supply and control systems.

In situ thermal desorption has been employed at the eight sites that are shown in Table 3-4. Most of these projects had no accidents or significant safety problems; however, the Rocky Mountain Arsenal project was terminated because of acidic corrosion of the above ground off-gas piping. Investigation showed widespread corrosion of the stainless steel piping. This was apparently caused when chlorinated organic compounds flowed directly into the extraction wells with essentially no residence time, resulting in hot aqueous hydrochloric acid in the off-gas collection system. Although no off-gas release occurred, the corrosion could have resulted in environmental release or personnel exposure if a pipe had been breached.

There is a potential for energetic reactions to occur between the buried sodium and potassium nitrates and carbonaceous materials such as oil, charcoal, graphite, and cellulosic materials when heated. A series of tests was conducted to evaluate the potential for these reactions to occur.[7] Fuels mixed or in contact with nitrates in 5- and 55-gal drums were subjected to heating rates of 100°C per hour, simulating in situ vitrification (ISV) processing conditions. The maximum testing temperature was 500°C. Explosions and intense burning occurred. It was concluded that combinations of nitrates with pyrolyzed rags or dry rags can deflagrate when subjected to simulated ISV heating rates. Nitrate-soaked rags undergo similar explosive reactions. Rapid reaction can occur over a wide range of stoichiometries and without intimate mixing. Depth of burial was studied as a method to mitigate explosive effects. Explosive effects of the maximum credible combination can be mitigated by 10 ft of dirt overburden. No hrther work was done to assess the effects of the slower heating rates associated with ISTD.

The ISTD system would be designed and constructed to meet SDA remediation requirements. Table 3-5 contains a checklist that identifies the applicable occupational hazards, including standard industrial hazards, and the DOE-prescribed occupational safety and health (OSH) standards that prevent or protect against them. Standard industrial hazards are hazards that are routinely encountered in general industry and construction; for these, national consensus codes or standards (such as the Occupational Safety and Health Administration) exist to guide safe design and operation. No special analysis of these occupational hazards is required unless they are possible initiators for an uncontrolled exposure to radioactive or nonradioactive hazardous materials.

Consequence Category	Off-Site Public
High (H)	greater than 25 rem or greater than ERPG-2
Moderate (M)	5 rem to 25 rem or ERPG-1 to ERPG-2
Low (L)	0.5 rem to 5 rem or TLV-TWA to ERPG-1
Negligible (N)	less than 0.5 rem or less than TLV-TWA



KEY

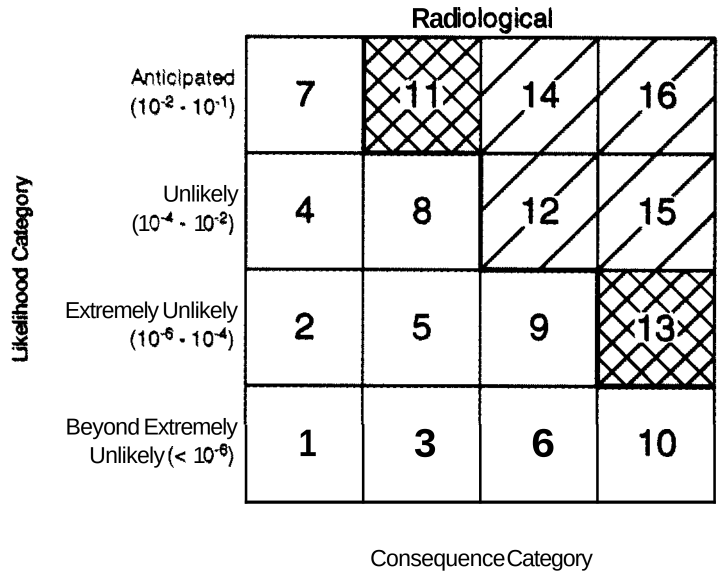
Safety-class SSCs and/or TSRs should be identified to manage off-site public risk; accident analysis may be needed.

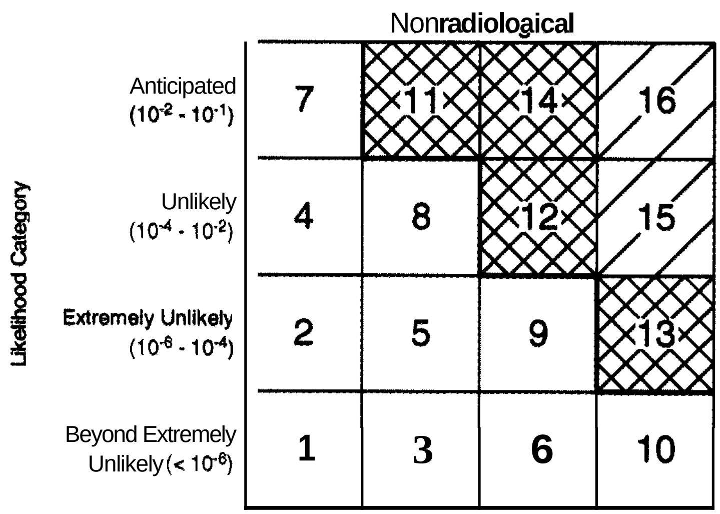
Safety-class SSCs or TSRs are generally not required to manage off-site public risk.

02-GA51330-01

Figure 3-1. Qualitative risk matrices for the offsite public.

Consequence Category	On-Site (Co-located) Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than ▲10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1





KEY

Safety-significant SSCs and/or TSRs should be identified to manage co-located worker risk; accident analysis may be needed.

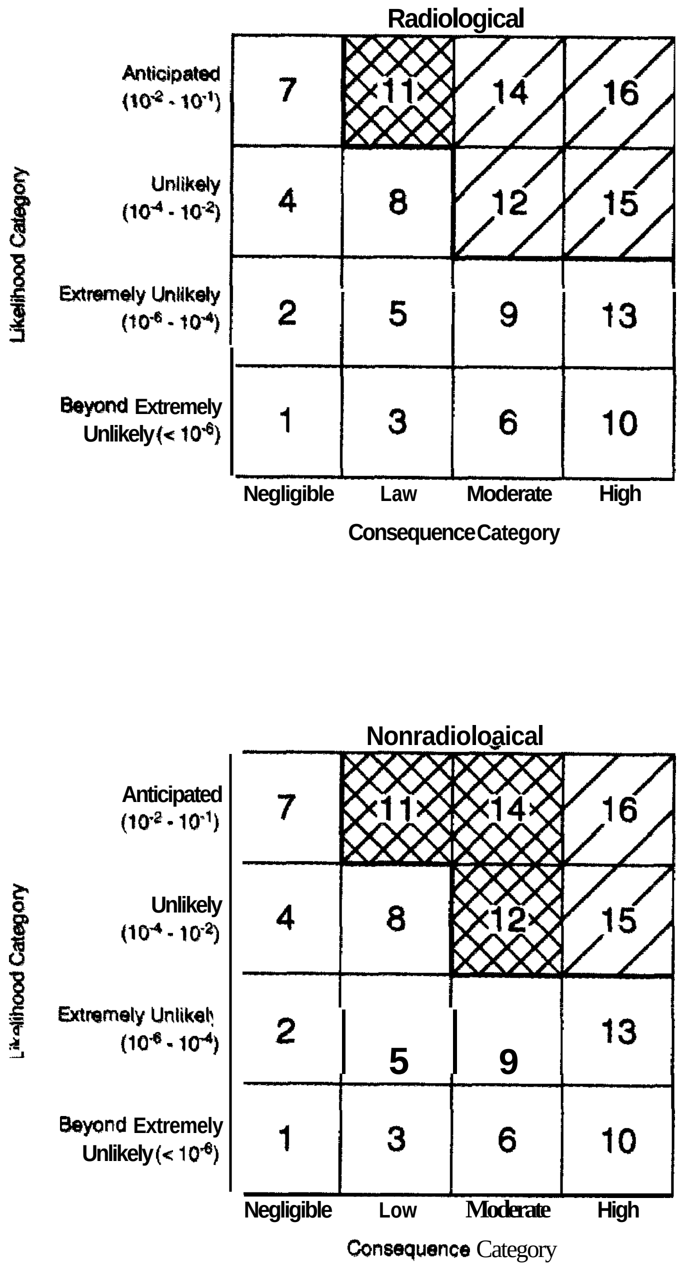
Safety requirements should be identified to manage co-located worker risk.

Safety SSCs, TSW, or safety requirements are generally not required to manage co-located worker risk.

02-GA51330-02

Figure 3-2. Qualitative risk matrices for collocated workers.

Consequence Category	Facility Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than ▲10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1



KEY

Safety-significant SSCs and/or TSRs should be identified to manage facility worker risk.

Safety requirements should be identified to manage facility worker risk.

Safety SSCs, TSRs, or safety requirements are generally not required to manage facility worker risk,

02-GA51330-03

Figure 3-3. Qualitative risk matrices for facility workers.

Table 3-3. Applicable entries from the ORPS database

Report Number	Event Description	Safety Significance
ORO-BNI-FUSRAPCISS-1996-0001	A thermal desorption process was being performed on approximately 2 ft^3 of waste material in an oily matrix in a heated 55-gal drum to remove organic halides. The system experienced three flashes directly above a port in the drum lid.	Demonstrates the capability for deflagrations to occur during thermal desorption processes.
RFO-K ILL-ENVOPS-1996-0010	During a project to treat soil and materials contaminated with volatile organic compounds by thermal desorption, high levels of contamination were detected in the trench where the materials were being excavated.	Demonstrates potential for hig ıer levels of transuranic contamination than were expected.
ALO-LA-LANL-TA55-1997-0020	The process exhaust ventilation for a plutonium processing and handling facility was lost because of adverse weather.	Containment ventilation systems that rely on external electrical power are vulnerable to failure from adverse weather.
RL-WHC-GROUT-1991-0180	Failure of a computer power supply unit caused an unplanned shutdown of the grout processing facility ventilation system.	The grout processing facility does not possess total redundancy in its computer control system. Ventilation systems must be properly designed and unplanned shutdowns can occur.

Table 3-4. Comparison of TerraTherm in situ thermal desomtion tests and remediations.

Demonstrations or Remediations	South Glens Falls	Saipan Lower Base	Portland	Cape Girardeau[a]	Eugene	Mare Island"	Centerville Beach	Rocky Mountain Arsenal
State	New York	Saipan	Indiana	Missouri	Oregon	California	California	Colorado
Type of site	Drag Strip, Superfund Site	Tanapag Village	Bailey Corporation	Electric Works Super fund Site	Railroad Bulk Fuel Terminal	Naval Facility	Naval Facility	Hex Pit with buried pesticides
Time Frame	1/96–3/96	7/97–8/98	7–12/97	6/97–9/98	6/97–9/98	8–11/97	9/98–2/99	2/00–6/02
Number of wells (vacuum and heating)	NA[e]	NA	130	12	761	12	53	266
Remediation[b] Temperature °C (°F)	500 (950)	500 (950)	300 (570)	480 (900)	300 (570)	320 (600)	340 (650)	325 (617)
Method of heat introduction	Thermal blankets	Thermal blankets	Wells	Wells	Wells	Wells	Wells	Wells
Organics remediated[c]	PCB	PCB	PCE, TCE	PCB	TPH	PCB, TCE	PCB	Pesticides
Before — organic (ppm)	5,000	10,000	35,000	20,000	9,000[d]	2,200	860	Not spec
After — organic (ppm)	< 0.8	<10	<0.08	<0.033	<1	<0.033	<1	NA
Volume treated (m^3)	200	800	900	90	2,000	120	750	2443
Area (m^3)	500	1700	150	30	700	30	150	668
Max depth (m)	0.4	0.6	6	3	3	4	5	12
Organic removed (lb/day)	0.1	NA	2	200	3,000	7	2	NA
Total cost ($/ton)[f]	150	NA	NA	200	120	130	300	558

a. Demonstrations
b. This is the minimum temperature reached throughout the site. Some areas were greater
c. TPH-total petroleum hydrocarbon, TCE-Trichloroethylene, PCB-Polychlorinated biphenyl, PCE-Perchloroethylene
d. Free product (diesel fuel) on water table
e. NA— not available
f. Costs are estimates and may not be comparable due to inclusion of different variables

Table 3-5. Hazard identification results.

Hazard	DOE-Prescribed Program and OSH standards	Hazard Sourceis)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Electrical	29 CFR 1910.137 29 CFR 1910.147 29 CFR 1910 Subpart S; 29 CFR 1926 Subparts K and V NEC 70	Electric equipment (>600 VAC)	Electrocution Fire	Transmission Lines SDA power loop Armored cable and transformer	No
		Electric distribution system and equipment (<600 VAC)	Electrocution Fire	Standby generator Off-gas treatment system trailers Control trailer Heater wells and vacuum heater wells	No
		Buried cable	Electrocution Fire	SDA power loop Heater wells	No
		On-ground cable (for example, mining cable)	Electrocution Fire	Armored cable Power to heater wells	No
		Low-hanging wires	Electrocution Fire	SDA	No
Volatile, flammable, or reactive gases or liquids	29 CFR 1910 Subpart H,.106,.144,.1200 29 CFR 1926.152	Propane tank	Asphyxiation, burns, BLEVE, fuel-air explosion	6,000-gal propane supply tank Off-gas system thermal oxidizer propane burner Propane fueled standby generator	No for asphyxiation and burns.[b] Yes for BLEVE, fuel-air explosion.
		Flammable/combustible liquids (including oil storage)	Burns	None	No
		Hydrogen gas	Deflagration	Buried waste	Yes
		Gasoline and diesel	Burns	Emergency backup power supply	Yes
Explosive materials	29 CFR 1910.109 29 CFR 1926 Subpart U DOE Explosive Safety Manual (DOE M 440-1)	Explicit explosives	Detonation	None	No
		Nitrate salts and pyrolyzed combustibles or finely divided graphite	Deflagration	Buried waste	Yes
Combustible materials	29 CFR 1910 Subpart L 29 CFR 1926 Subpart F	Combustible materials in treatment area	Fire in ISTD equipment	SDA Off-gas treatment system Heater wells	Yes
Cryogenic systems	DOE Order 440.1A	Liquid nitrogen	Frostbite	None	No

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Piping and vessels	ASME Boiler and Pressure Vessel Code, ANSI/ASME Standard B31	Fired and unfired pressure vessels	Projectiles	Propane tank	No
		Break in off-gas piping	Personnel exposure	Off-gas system	Yes
Pressurized liquid systems	National Fire Protection Association	Pressurized water (for example, firewater)	Personnel injury	SDA	No
		Hydraulic system	Personnel injury	Support equipment	No
Compressed gas	29 CFR 1910.101 and Subpart M CGA P-1 (1965), Safe Handling of Compressed Gases	Cylinders of various gases, compressed air supply	Projectiles	SDA	Yes
		Buried compressed gas cylinders	Projectiles	SDA	Yes
		Hydrogen buildup in sealed containers	Projectiles	SDA	Yes
Low pressure		Not Applicable	Not Applicable	None	No
Inert and low-oxygen atmospheres	29 CFR 1910.120, .1200 29 CFR 1926.651 and Subparts D, E	Confined space	Asphyxiation	None	No
Nonradioactive hazardous materials	29 CFR 1910.119, .120, ,1200, and Subpart Z 1926.353 and Subparts D, E, Z; ACGM TLVs	Asbestos	Personnel exposure	Buried waste	Yes
		Carbon monoxide	Personnel exposure	Off-gas treatment system	Yes
		Chemical hazards (cleaning, and so forth)	Personnel exposure, poisoning	None	No
		Buried chemicals	Personnel exposure, poisoning	Buried waste	Yes
		Subsidence exposes buried waste	Personnel exposure	SDA	Yes
		Freon 22, Halon	Frostbite, asphyxiation, cardiac effects	None	No

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Sourceis)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
		Lead	Personnel exposure, poisoning	Buried waste	Yes
		Hazardous (mixed) waste	Personnel exposure, poisoning	Buried waste	Yes
		v o c s	Personnel exposure, poisoning	Buried waste	Yes
Nonionizing radiation	29 CFR 1910.97 29 CFR 1926.54 ACGIH TLVs, ANSI Z 136	Barcode scanning laser	Eye damage	None	No
		Electromagnetic fields generated by power systems	Health effects	None	No
High intensity magnetic fields	ACGIH TLVs	Not applicable	Not applicable	None	No
High noise levels	29 CFR 1910.95,.1200 29 CFR 1926.52; ACGIH TLVs	High noise from operating equipment	Hearing damage	Off-gas treatment system	No
Mechanical and moving equipment dangers	29 CFR 1910.147,.211 through .219; 29 CFR 1910 Subparts O, P, Q; 29 CFR 1926 Subparts N, O, W	Rotating equipment (that is, HVAC equipment, belts, conveyors)	Personnel injury	Drilling equipment to place heater wells Off-gas treatment system	No
		Vehicle/forklift traffic	Impact with personnel Damage to off-gas hood and off-gas treatment system	SDA Vacuumheater well headers Off-gas treatment system	No
Working at heights	29 CFR 1910.25,.28 29 CFR 1926.951,.451	Ladders/platforms, bridges, high equipment, pits	Personnel falling	None	No

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Excavation	29 CFR 1926 Subpart P	Disposal areas	Buried waste uncovered during heater well placement	SDA	No
Material handling dangers	29 CFR 1910.120,.176 through .182 29 CFR 1926.953; DOE-STD-1090-2001 Hoisting and Rigging	Cranes, forklifts	Crushmg personnel	Installation of ISTD equipment	No
Material transportation (onsite and offsite)	Hazardous Material Transportation Program, DOE Orders 460.1A and 460.2	Hazardous materials	Personnel exposure	None	No
Pesticide, herbicide, and rodenticide use	29 CFR 1910.1200	Pesticides, herbicides, rodenticides-	Poisoning	None	No
Temperature extremes (high and low temperatures during activities)	29 CFR 1910.120, 29 CFR1910.132(a), 29 CFR1910.133(a), 29 CFR1910.138(a), .Z1200; ACGM TLVs	Ambient temperatures	Hypothermia, frostbite, heat stress Fire Burns	ISTD treatment area Off-gas piping and header network Off-gas treatment system	No
		Molten material beneath overburden	Heat stress Fire Burns	ISTD treatment area	Yes
		High temperature equipment	Burns	ISTD off-gas treatment system thermal oxidizer operates up to 1,700°F.	No
		Off-gases	Heat stress Fire Burns	ISTD treatment area Vacuumheater wells and headers Off-gas treatment system	Yes
Inadequate illumination	29 CFR 1910.37, .68,.110,.120, .177 through .179, .219, .303 29 CFR 1926.C26	Inadequate lighting	Tripping or falling	Trailers Outside ISTD work areas	No
Construction	29 CFR 1926	General construction hazards	Personnel injury	None	No

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Sourceis)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Ionizing radiation	29 CFR 1926.53, Occupational Radiation Protection, 10 CFR 835	Radioactive waste	Personnel exposure	SDA Off-gas treatment system	Yes
	ANSIN43.3	Ionizing radiation generating devices.	Personnel exposure	None	No
Radioactive materials	Radiation Protection Program 10 CFR 835	Radioactive waste	Personnel exposure	SDA Vacuumheater wells and well headers Off-gas treatment system	Yes
		Subsidence exposes buried waste	Personnel exposure	SDA	Yes
Fissile materials	Criticality Safety Program	Sources (in a storage cabinet)	Criticality	None	No
	DOE Order 420.1A DOE-STD-3007	Radioactive waste	Criticality	SDA	Yes
Reactive Materials: Alkali Metal and Corrosives	Chemical Safety Program DOE Order 5480.4; 29 CFR 1910.21200, ,21450	Pyrophoric materials in buried waste	Fire	SDA	Yes
Structural or Natural Phenomena	DOE Order 420.1, DOE-ID AE Standards DOE-GDE-420.1-2 29 CFR 1910.H119, Subpart E	Lightning, strong wind, tornado, earthquake, and so forth	Other material and energy sources listed in this table, these are initiators.	SDA Vacuumheater well headers Off-gas treatment system	Yes
Fire	Fire Protection Program, DOE Order 420.1	Combustibles (solids and gases)	Burns Failure of off-gas system	SDA ISTD treatment area	Yes[c]
Biological Agents	DOE Order 440.1A	Hantavirus	Personnel exposure	SDA	No
		Biological assays	Personnel exposure	None	No
		Sewage	Personnel exposure	None	No

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Other	29 CFR 1910, DOE Order 440.1A	Low overhead	Head injury	None	No
		Pinch point (carts, doors, shrink wrap equipment)	Injury to extremities	None	No
		Uneven or slick walkmg surfaces, trip/fall hazards	Tripping or falling	SDA	No
		Objects at height (for example, shelves, overhead crane work, waste handling)	Objects falling onto personnel	None	No
		Water heater, boiler, tank, soldering surface	Burns	None	No
		Exhaust pipe	Burns	Support equipment	No
External events	Not applicable	The AMWTP is a potential source for hazards addressed in the previous rows. No hazards unique to AMWTP were identified.	Not applicable	SDA	No
		Loss of off-site power	Failure of off-gas system	Vacuumheater well headers Off-gas treatment system	Yes[d]
		Range fire	Causes failure of off-gas system	Vacuumheater well headers Off-gas treatment system	Yes[d]
		Aircraft (helicopter and fixed wing) crash	Impact, fire, initiator for another hazard	ISTD treatment area Vacuumheater well headers Off-gas treatment system	Yes[d]

Table 3-5. (continued)

Hazard	DOE-Prescribed Program and OSH standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]

a. This question pertains to further consideration of the hazard identified here and not to initiators for another hazard. All hazards, even those dismissed here, are considered as initiators for other hazards. For example, fires from propane tanks or batteries are not considered further as a direct hazard, but they are considered as initiators for waste fires that could result in release of radioactive or hazardous material.

b. Flammable gases or liquids are considered later as a fuel source for fires that could result in a release of radioactive and chemically hazardous materials.

c. Fire is considered as a potential cause for the release of radioactive and chemically hazardous materials.

d. External events are considered as initiators for release of radioactive and chemically hazardous materials.

ACGIH American Conference of Government Industrial Hygienists
AE Architectural Engineering
AMWTP Advanced Mixed Waste Treatment Project
ANSI America National Standards Institute
ASME American Society of Mechanical Engineers
BLEVE boiling liquid-expansion vapor explosion
CFR Code of Federal Regulations
CGA Compressed Gas Association
DOE U.S. Department of Energy
DOE-ID U.S. Department of Energy Idaho Operations Office
HVAC heating, ventilating, and air conditioning
ISTD in situ thermal desorption
NEC National Electric Code
OSH occupational safety and health
SDA Subsurface Disposal Area
TLV threshold limit value
VOC volatile organic compound

3.3.2.1.2 Radioactive and Nonradioactive Hazardous Material Inventory — This section discusses the radioactive and nonradioactive hazardous material inventories that will be used for the hazard and accident analyses in this document. The inventory in the SDA generally consists of solid radioactive waste from the INEEL, RFP, and other offsite generators.

The total inventory in the SDA is estimated using the historical data task (HDT)[8] and recent and projected data task (RPDT)[9] reports. The HDT report contains best-estimate, lower-bound, and upper-bound total quantities of radioactive and nonradioactive hazardous materials buried between 1952 and 1983. The RPDT report contains similar historical information for 1984 through 1993, and projected quantities from 1994 through 2003. The RPDT has been updated with the actual disposals to 1999.[10] The total activity for some radionuclides has also been updated to reflect currently accepted values reported in Table 3-7 of the ancillary basis for risk analysis (ABRA) report.'' Carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane contents have been updated from a study by Varvel.[12]

The development of these inventories is described in Engineering Design File (EDF)-3543, "SDA Inventory Evaluation for ISG, ISV, and ISTD PDSA Source Terms".[13] The EDF addresses all waste types buried in the RWMC SDA, including transuranic (TRU) waste and non-TRU (contact-handled [CH] LLW and remote-handled [RH] LLW). It also addresses nonradioactive contaminants that are part of the mixed TRU and non-TRU waste.

In situ thermal desorption is being considered for remediation of pits 4, 5, 6, and 10. These pits were used for disposal of drums containing sodium and potassium nitrate sludges (waste code 745) and organic sludges (waste code 743). Both types of waste are contaminated with plutonium. In situ thermal desorption has the ability to decompose these waste types and thus reduce the hazard; however, the hazard analysis will be based on the entire SDA, which will envelope the conditions found in those pits. The areas being considered contain primarily drums.

Radioactive Material Inventory

Table 3-6 shows the total quantities of radioactive materials and the quantity of each radionuclide disposed for each time period, as well as the total for all time periods. The total best-estimate activities have been updated to reflect current data from the ABRA report.'' Because the data from the ABRA report are cumulative, the updated total best-estimate activity value for a radionuclide is not necessarily equal to the sum of the activity values for the time intervals. Activity levels are those at the time of disposal, without consideration of radioactive decay.

Table 3-6. Radioactive hazardous materials in the RWMC SDA.

Radionuclide	52–83 Best-estimate (Ci)	84–93 Best-estimate (Ci)	94–99 Best-estimate (Ci)	Total Best-estimate (Ci)	Percent of Total Activity (%)
Am-241	1.5E+05	3.7E+00	1.8E+00	1.83E+05	1.3E+00
Pu-239	6.6E+04	2.4E+00	1.8E-01	6.49E+04	4.8E-01
Pu-241	4.0E+05	1.7E+01	1.0E+01	9.74E+05	7.1E+00
Pu-240	1.5E+04	5.7E-02	1.0E-01	1.71E+04	1.3E-01
Pu-238	2.5E+03	3.6E-01	1.7E-01	1.71E+04	1.3E-01
Sr-90	4.5E+05	5.8E+02	6.2E+01	6.44E+05	4.7E+00
Co-60	2.8E+06	1.4E+06	2.8E+04	2.20E+06	1.6E+01

Table 3-6. (continued).

Radionuclide	52–83 Best-estimate (Ci)	84–93 Best-estimate (Ci)	94–99 Best-estimate (Ci)	Total Best-estimate (Ci)	Percent of Total Activity (%)
Am-243	2.3E-01	None	6.8E-06	1.34E+02	9.8E-04
Ce-144	1.5E+05	2.1E+02	1.4E+01	1.5E+05	1.1E+00
Cm-244	8.0E+01	7.6E-02	9.2E-02	8.0E+01	5.9E-04
Cs-137	7.0E+05	3.1E+03	7.2E+01	6.17E+05	4.5E+00
U-238	1.1E+02	1.6E+00	1.2E+00	1.17E+02	8.6E-04
Fe-55	3.8E+06	1.6E+05	2.1E+04	4.0E+06	2.9E+01
U-234	6.4E+01	3.5E+00	2.5E+00	6.74E+01	4.9E-04
Ni-63	7.4E+05	4.8E+05	5.3E+04	1.32E+06	9.7E+00
U-232	8.4E+00	2.2E+00	5.1E-03	1.06E+01	7.8E-05
Pu-242	9.9E-01	1.2E-08	4.2E-08	1.65E+01	1.2E-04
Co-58	1.6E+05	2.0E+05	1.9E+03	3.6E+05	2.7E+00
Th-228	None	1.0E+01	7.7E-03	1.02E+01	7.5E-05
Ru-106	6.8E+03	6.4E+01	4.5E+00	6.9E+03	5.0E-02
Th-232	1.3E+00	None	2.6E-02	1.34E+00	9.8E-06
Mn-54	1.8E+05	1.2E+05	2.3E+03	3.0E+05	2.2E+00
Zr-95	7.6E+04	2.1E+03	1.2E+02	7.8E+04	5.7E-01
Sb-125	1.3E+05	2.9E+03	1.5E+03	1.3E+05	9.9E-01
Cm-242	9.1E+01	8.8E-02	1.3E-01	9.1E+01	6.7E-04
Fe-59	9.1E+04	1.5E+04	2.7E+00	1.1E+05	7.8E-01
Np-237	2.4E+00	3.7E-03	9.4E-03	2.64E+00	1.9E-05
Eu-154	3.0E+03	3.3E+00	1.5E+02	3.00E+03	2.2E-02
Ta-182	8.5E+00	1.8E+04	4.1E+02	1.8E+04	1.4E-01
U-235	5.1E+00	1.6E-01	2.7E-01	5.54E+00	4.1E-05
Eu-155	1.5E+04	3.9E+01	8.2E+01	1.5E+04	1.1E-01
Ra-226	5.9E+01	1.1E+00	7.9E-02	6.00E+01	4.4E-04
Nb-94	4.9E+01	2.0E-01	2.8E-01	1.00E+03	7.3E-03
U-236	2.5E+00	2.3E-03	4.7E-03	2.86E+00	2.1E-05
Cr-51	7.3E+05	4.7E+04	6.1E+02	7.8E+05	5.7E+00
Sn-119m	2.7E+04	8.8E+03	9.1E+00	3.6E+04	2.6E-01
U-233	1.1E+00	None	3.6E-01	1.5lE+00	1.1E-05
Y-90	1.9E+04	2.0E+02	2.4E+01	1.9E+04	1.4E-01
Cs-134	2.2E+03	1.4E+02	3.2E+00	2.3E+03	1.7E-02
H-3	1.2E+06	3.0E+05	4.4E+03	1.50E+06	1.1E+01
Co-57	4.8E+00	1.5E+00	7.2E+03	7.2E+03	5.3E-02
Eu-152	2.4E+02	4.1E+00	2.5E+01	2.7E+02	2.0E-03
Hf-181	3.6E-01	3.4E+03	8.4E+00	3.4E+03	2.5E-02

Table 3-6. (continued).

Radionuclide	52–83 Best-estimate (Ci)	84–93 Best-estimate (Ci)	94–99 Best-estimate (Ci)	Total Best-estimate (Ci)	Percent of Total Activity (%)
Sb-124	1.8E+03	1.1E-02	5.1E-01	1.8E+03	1.3E-02
Nb-95	2.4E+03	3.8E+03	1.6E+00	6.2E+03	4.6E-02
Zn-65	3.6E+02	1.0E+03	2.2E+03	1.36E+03	1.0E-02
Y-91	5.3E+02	None	8.6E-06	5.3E+02	3.9E-03
Ni-59	5.1E+03	1.4E+03	4.4E+02	6.9E+03	5.1E-02
Sr-89	4.7E+02	3.0E+00	8.8E+00	4.10E+02	3.0E-03
Hf-175	None	2.8E+03	4.2E-02	2.8E+03	2.1E-02
Th-230	1.8E-02	None	1.3E-02	3.13E-02	2.3E-07
Ce-141	7.6E+02	2.9E+00	1.5E-01	7.6E+02	5.6E-03
Pr-143	6.2E+02	None	None	6.2E+02	4.6E-03
W-185	None	6.4E+03	None	6.4E+03	4.7E-02
Pm-147	8.1E+01	2.4E+00	2.6E+01	1.1E+02	8.1E-04
Sc-46	5.3E+01	5.0E+01	3.4E+01	1.4E+02	1.0E-03
La-140	7.7E+02	2.8E+00	6.6E-02	7.7E+02	5.7E-03
Ir-192	5.4E+01	6.6E-01	7.0E+01	1.2E+02	9.1E-04
Ru-103	3.6E+02	1.9E-01	1.1E-02	3.6E+02	2.6E-03
Na-22	3.0E-01	5.4E-01	3.7E+02	3.7E+02	2.7E-03
Ba-140	6.6E+02	2.4E+00	6.8E-02	6.6E+02	4.9E-03
Pr-144	4.2E+04	1.1E+02	2.2E+00	4.2E+04	3.1E-01
Cf-252	1.0E-02	None	None	1.0E-02	7.3E-08
Be-10	4.3E+01	None	1.0E-10	4.3E+01	3.2E-04
Zr-93	4.0E+00	None	3.1E-05	4.0E+00	2.9E-05
C-14	1.6E+04	4.0E+01	1.8E+01	5.00E+02	3.7E-03
Cd-109	4.1E-01	1.1E-02	5.2E-04	4.2E-01	3.1E-06
Tc-99	2.6E+02	5.0E-01	9.0E-01	6.05E+01	4.4E-04
Sn-l17m	None	1.2E+02	1.7E-09	1.2E+02	8.8E-04
Te-125m	None	4.2E+01	1.0E-02	4.2E+01	3.1E-04
Sn-113	None	2.4E+01	4.6E+00	2.9E+01	2.1E-04
Tm-170	3.4E+00	None	None	3.4E+00	2.5E-05
1-131	1.5E+00	1.1E-01	6.0E-02	1.7E+00	1.2E-05
Rb-86	7.1E+00	None	None	7.1E+00	5.2E-05
Gd-153	None	1.3E+00	8.7E-02	1.4E+00	1.0E-05
1-129	9.9E-02	2.1E-03	5.3E-03	1.58E-01	1.2E-06
C1-36	3.1E-01	None	9.2E-02	1.1lE+00	8.1E-06
Ag-108m	None	1.1E-07	7.1E-02	7.1E-02	5.2E-07
Mn-56	2.7E+01	1.3E+00	None	2.8E+01	2.1E-04

Table 3-6. (continued).

Radionuclide	52–83 Best-estimate (Ci)	84–93 Best-estimate (Ci)	94–99 Best-estimate (Ci)	Total Best-estimate (Ci)	Percent of Total Activity (%)
Cs-136	7.7E-01	None	None	7.7E-01	5.7E-06
Mo-99	1.0E+00	2.3E-02	2.2E-02	1.0E+00	7.7E-06
Na-24	None	2.7E+00	1.6E-02	2.7E+00	2.0E-05
Ag-110m	None	1.8E-02	2.8E-01	3.0E-01	2.2E-06
V-48	None	2.0E-01	None	2.0E-01	1.5E-06
P-32	9.2E-02	None	1.4E-11	9.2E-02	6.8E-07
Rh-103m	2.7E+02	None	1.3E-02	2.7E+02	2.0E-03
Y-88	2.5E-02	3.0E-03	7.1E-05	2.8E-02	2.1E-07
1-125	2.9E-02	None	8.2E-04	3.0E-02	2.2E-07
Se-75	None	4.5E-02	2.9E-02	7.4E-02	5.4E-07
Am-242	7.6E-03	None	None	7.6E-03	5.6E-08
1-132	None	1.0E+00	1.5E-01	1.2E+00	8.4E-06
1-133	5.0E-02	1.5E-03	None	5.2E-02	3.8E-07
s-35	8.8E-02	None	1.2E-02	1.0E-01	7.4E-07
Y-93	None	1.1E-01	None	1.1E-01	8.1E-07
Sr-85	2.9E-02	None	7.8E-04	3.0E-02	2.2E-07
Be-7	3.5E-01	None	None	3.5E-01	2.6E-06
Hg-203	1.2E-02	None	None	1.2E-02	8.8E-08
Po-210	7.5E+01	None	5.1E-07	9.10E-06	6.7E-11
Au-198	None	2.4E-02	None	2.4E-02	1.8E-07
Te-132	None	5.6E-03	6.7E-17	5.6E-03	4.1E-08
Ra-225	2.0E-06	None	2.5E-06	4.5E-06	3.3E-11
Pb-212	2.0E-05	None	1.7E-04	1.9E-04	1.4E-09
Re-188	None	9.3E-03	None	9.3E-03	6.8E-08
Er-169	7.6E-03	None	None	7.6E-03	5.6E-08
sc-44	2.5E-02	None	None	2.5E-02	1.8E-07
Sr-91	None	4.4E-03	None	4.4E-03	3.2E-08
Pb-210	9.1E-06	None	5.1E-07	5.10E-07	3.7E-12
Ba-133	5.4E-04	None	3.4E-04	8.8E-04	6.4E-09
Ca-45	6.7E-04	None	None	6.7E-04	4.9E-09
In-113m	None	8.2E-02	6.4E-04	8.3E-02	6.1E-07
Ce-139	None	3.0E-04	2.8E-06	3.0E-04	2.2E-09
T1-204	6.7E-04	None	None	6.7E-04	4.9E-09
Br-82	None	1.0E-03	None	1.0E-03	7.3E-09
Sr-92	None	1.6E-03	None	1.6E-03	1.2E-08
Mn-53	1.0E-03	None	None	1.0E-03	7.3E-09

Table 3-6. (continued).

Radionuclide	52–83 Best-estimate (Ci)	84–93 Best-estimate (Ci)	94–99 Best-estimate (Ci)	Total Best-estimate (Ci)	Percent of Total Activity (%)
Cd-104	1.5E-07	None	None	1.5E-07	1.1E-12
Ag-110	8.4E-01	1.9E+00	5.9E-03	2.7E+00	2.0E-05
Ba-137m	3.4E+00	4.6E+00	8.5E+00	1.6E+01	1.2E-04
Kr-85	1.3E+00	None	1.9E-03	1.3E+00	9.6E-06
Rh-106	6.8E+03	6.1E+01	1.8E+00	6.9E+03	5.0E-02
Rn-222	1.0E-06	None	5.8E-07	1.6E-06	1.2E-11
Xe-133	None	None	None	None	None
Yb-164	7.6E-03	None	None	7.6E-03	5.6E-08

Transuranic Waste

Transuranic waste is radioactive waste that contains alpha-emitting radionuclides with an atomic number greater than 92 (elements heavier than uranium) and a half-life greater than 20 years. During the period when TRU waste was buried in the SDA, TRU was defined to have an activity concentration greater than 10 nCi/g. TRU waste is of particular concern because of its long-lived radioactivity and high radiological dose consequences when inhaled. Transuranic waste disposal was terminated at the SDA in 1970.

Subsurface Disposal Area Pits 1–6 and 9–12, and trenches 1–10 are known to contain TRU waste. Trenches 11–15 are also suspected to contain TRU waste. RFP waste in drums and boxes was disposed in Pits 11 and 12 through 1972. Later these drums were retrieved and the TRU drums placed in the Transuranic Storage Area. The boxes were left in Pits 11 and 12, so TRU could have been disposed then. Also there are a small number of TRU drums on Pad A.

Transuranic waste consists of a wide variety of materials, including large quantities of solidified nitrate salt and organic sludges, gloves, paper, plastics, rags, and other combustible wastes; various tools and other light metal or steel wastes; heavy metal wastes (such as tantalum molds and funnels); graphite mold materials (chunks and fines); glass; and other items used in day-to-day RFP glovebox operations.

The majority of metal drums in the SDA is assumed breached, because of corrosion or physical damage to the drum during dumping and burial, and can no longer provide adequate waste containment of their contents.[14] Although most recent RFP waste drums have a poly drum liner, the poly drum liners were not used until late 1972; therefore, none are assumed present in the SDA. Earlier retrieval efforts did observe some leaking containers indicating unabsorbed or desorbed free liquid drums.[15]

Table 3-7 shows the radioactive hazardous material inventory for accidents involving TRU drums with likelihood categories of anticipated, unlikely, and extremely unlikely. Information about drum inventories has been derived from the following:

- Acceptable knowledge reports based on shipping records
- Data from assaying stored drums being shipped to the Waste Isolation Pilot Plant (WIPP)
- Data from SDA subsurface probes.

Table 3-7. Inventory for accident scenarios involving a single TRU drum.

Single Drum Cases	Mass Content (g)		Activity Content (Ci)		Data Source
	Pu-239-eq	Am-241	Pu-239-eq	Am-241	
Upper Bound Drum (extremely unlikely)	2,217	71	140	240	Probe Data for Pu Acceptable knowledge for Am
Limiting Drum (unlikely)	510	31	31.8	105	Haefner Report[16] for Pu-equiv Acceptable knowledge for Am
Average Drum (anticipated)	58	0.22	3.6	0.74	Haefner Report for Pu-equiv Acceptable knowledge for Am

Notes:

Pu-239-eq is amount Pu-239 equivalent to a quantity of Rocky Flats plutonium (Pu-238 through Pu-242 radionuclides and ingrown Am-241).[16]

Use either Pu-239-eq or Am-241, but not both. Haefner report includes Am-241 in calculating Pu-239-eq. For upper bound and limiting drums, finding both bounding inventories in the same drum is considered beyond extremely unlikely. An average drum would be expected to contain either Pu-239-eq or Am-241 alone, but not both.

Pu-239-eq curies converted to grams using the specific activity of 0.062 Ci Pu-239-eq / gm. Pu-239-eq from Haefner.

3.3.2.2 ***Direct Radiation Sources.*** Subsurface Disposal Area shipping records show the SDA pits and trenches contain 861 packages with surface radiation exposure rates above 1 R/hr at the time of disposal. Dose rates for materials in the soil vaults have not been characterized, but are expected to be similar. Sixty-seven of the packages in the pits and trenches had surface exposure rates of 100 R/hr or greater. Most of the RH sources are from the INEEL. Only eight of these packages were buried in the pits, with the rest in trenches. The last RH disposal in a trench was September 25, 1981. After that, RH packages were disposed of in soil and concrete vaults. The predominant known radionuclide is Co-60, and the unknown radionuclides are also believed to be mostly Co-60, but include a variety of fission and activation products.

The highest exposure package was 150,000 R/hr at the surface. Since it is identified as Co-60 with a disposal date of January 17, 1963, its current exposure rate is approximately 800 R/hr. The next highest surface exposure rate is 24,000 R/hr from unknown radionuclides. Since the radionuclide is unknown, its decay cannot be accurately calculated; thus, the direct radiation surface exposure rate for potential accident calculations is conservatively bounded at 24,000 R/hr. Remote-handled LLW was disposed of in many different packages and configurations. The largest commonly used package is an internal canister that fits the 55-ton cask. The package has a diameter of 46.6 in; thus, it is conservatively assumed the surface of the 24,000 R/hr package is 2 ft from the center axis.

For the pits being considered for ISTD (pits 4, 5, 6, and 10), the only disposed packages above 1 R/hr were two packages in Pit 10 that were 5 R/hr and 2 R/hr.

Low-level Waste

Low-level waste is non-TRU waste that contains beta- and gamma-emitting radionuclides. Low-level waste is still being disposed. Non-TRU wastes from the INEEL are in all pits and trenches, and include activation and fission products from reactor operations at the site. The wastes include various reactor core, vessel, and loop components; as well as resins and discarded laboratory materials. Beryllium blocks, expended fuel, and contaminated metal and debris from demolition projects at the INEEL are also buried in the SDA. Non-TRU waste from offsite generators includes biological wastes, laboratory wastes, and other items contaminated with radioactive material.

Low-level waste is classified by its handling requirements as CH-LLW or RH-LLW. Remote-handled LLW has exposure rates above 500 mR/h at a 1-m distance from the waste package surface. Remote-handled LLW was buried in pits, trenches, and soil vaults. Trenches received high-radiation waste until trench disposal was discontinued in 1981. Soil vault disposals were conducted until 1995. Remote-handled LLW is currently disposed of in the active pits and in concrete vaults located in the active pits.

The TRU drum inventories in Table 3-7 do not include the fission and activation products because of the following:

- Most fission and activation products are not contained in the same drums and boxes as TRU.
- Most activation products are expected to be discrete RH-LLW packages buried in the trenches and vaults.
- Most fission products are probably in resins or nuclear fuel-related material that would be discrete from activation products or TRU packages.

The direct radiation information is used to estimate the maximum quantity of LLW activation products in a single package. If the 24,000 R/hr source term were entirely Co-60, the Co-60 content would be 17,500 Ci, without taking credit for decay. This inventory would be bounding for the pits and trenches. Packages in the soil vaults have not been characterized, but are expected to be similar. If only pits 4, 5, 6, and 10 are considered, the maximum source would be 3.7 Ci of Co-60, corresponding to a 5 R/hr source.

Information on LLW inventories in the SDA is shown in Table 3-8. The radionuclides in Table 3-8 are the fission and activation products that comprise at least 1% of the total inventory. Some volatile radionuclides, such as antimony, iodine, krypton, cadmium, lead, and mercury are not included because of their lower inventory and relatively low inhalation hazard.

Table 3-8. Estimated inventory for significant LLW radionuclides at the SDA.

Radionuclide	Total Upper-bound Inventory (Ci)	Bounding Average Inventory (Ci/ ft^2)	Total Best-estimate Inventory (Ci)	Best-estimate Average Inventory (Ci/ ft^2)
Co-60	9.4E+06	2.4E+01	2.2E+06	1.8E+00
Fe-55	6.3E+06	1.6E+01	4.0E+06	3.3E+00
Cr-51	4.8E+06	1.2E+01	7.8E+05	6.4E-01
H-3	3.8E+06	9.7E+00	1.5E+06	1.2E+00
Ni-63	2.2E+06	5.7E+00	1.3E+06	1.1E+00
Co-58	1.7E+06	4.4E+00	3.6E+05	3.0E-01
Mn-54	1.4E+06	3.6E+00	3.0E+05	2.5E-01
Sr-90	1.3E+06	3.3E+00	6.4E+05	5.3E-01
Cs-137	9.6E+05	2.5E+00	6.2E+05	5.1E-01
Ce-144	5.2E+05	1.3E+00	1.5E+05	1.2E-01

3.3.2.3 ***Nonradioactive Hazardous Material Inventory.*** The RWMC contains large quantities of nonradioactive contaminants. Table 3-9 lists the nonradioactive contaminants in the SDA ordered alphabetically. Updated best-estimate values for carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane are from Varvel.[14]

The most abundant and hazardous contaminants are sodium and potassium nitrates; organics, particularly carbon tetrachloride; and metals such as lead, beryllium, and zirconium. The nitrates (primarily 745 sludge) resulted from evaporation of high nitrate waste in ponds at RFP. Because of the landfill disposal methods used during the 1960s, potassium or sodium nitrates were dumped into the same area as organic materials. A mixture of nitrates and organics is seen as potentially explosive.

Table 3-9. Nonradioactive hazardous material inventory.

Contaminant	Upper-bound Inventory (g)	Bounding Inventory Density (g/drum)	Bounding Inventory Density (g/ft^2)	Average Inventory Density (g/drum)	Average Inventory Density (g/ft^2)
1,1,1-trichloroethane	1.2E+08	3.9E+04	1.4E+04	3.2E+02	1.7E+02
1,1,2-trichloro-1,2,2-trifluoroethane	9.5E+06	3.1E+03	1.1E+03	2.5E+01	1.3E+01
2-butanone	4.0E+04	1.3E+01	4.6E+00	1.1E-01	5.6E-02
Acetone	1.3E+05	4.2E+01	1.5E+01	3.4E-01	1.8E-01
Aluminum nitrate nonahydrate	2.4E+08	7.7E+04	2.7E+04	6.4E+02	3.4E+02
Ammonia	1.8E+06	5.8E+02	2.1E+02	4.8E+00	2.5E+00
Anthracene	4.6E+02	1.5E-01	5.3E-02	1.2E-03	6.5E-04
Antimony	1.0E+03	3.2E-01	1.1E-01	2.7E-03	1.4E-03
Aqua regia	3.2E+01	1.0E-02	3.7E-03	8.5E-05	4.5E-05
Arsenic	1.1E+00	3.6E-04	1.3E-04	3.0E-06	1.6E-06
Asbestos	4.8E+06	1.5E+03	5.5E+02	1.3E+01	6.7E+00
Barium	1.2E+01	3.9E-03	1.4E-03	3.2E-05	1.7E-05
Benzine	4.8E+03	1.5E+00	5.5E-01	1.3E-02	6.7E-03
Beryllium	7.3E+07	2.4E+04	8.4E+03	1.9E+02	1.0E+02
Butyl alcohol	1.1E+05	3.5E+01	1.3E+01	2.9E-01	1.5E-01
Cadmium	2.3E+06	7.4E+02	2.6E+02	6.1E+00	3.2E+00
Carbon tetrachloride	8.2E+08	1.3E+05	4.7E+04	2.2E+03	1.2E+03
Cerium chloride	6.2E+05	2.0E+02	7.1E+01	1.6E+00	8.7E-01
Chloroform	3.7E+01	1.2E-02	4.2E-03	9.8E-05	5.2E-05
Chromium	1.6E+03	5.1E-01	1.8E-01	4.2E-03	2.2E-03
Copper	4.5E+04	1.5E+01	5.2E+00	1.2E-01	6.3E-02
Copper nitrate	4.1E+02	1.3E-01	4.7E-02	1.1E-03	5.8E-04
Ethyl alcohol	2.8E+04	9.0E+00	3.2E+00	7.4E-02	3.9E-02
Formaldehyde	1.5E+05	4.8E+01	1.7E+01	4.0E-01	2.1E-01
Hydrazine	2.3E+03	7.4E-01	2.6E-01	6.1E-03	3.2E-03
Hydrofluoric acid	9.4E+06	3.0E+03	1.1E+03	2.5E+01	1.3E+01
Lead	7.8E+08	2.5E+05	8.9E+04	2.1E+03	1.1E+03
Magnesium	1.1E+07	3.5E+03	1.3E+03	2.9E+01	1.5E+01

Table 3-9. (continued).

Contaminant	Upper-bound Inventory (g)	Bounding Inventory Density (g/drum)	Bounding Inventory Density (g/ft^2)	Average Inventory Density (g/drum)	Average Inventory Density (g/ft^2)
Magnesium fluoride	1.4E+05	4.5E+01	1.6E+01	3.7E-01	2.0E-01
Mercury	2.0E+06	7.1E+03	2.5E+03	5.2E+00	2.7E+00
Mercury nitrate monohydrate	1.0E+06	3.2E+02	1.1E+02	2.7E+00	1.4E+00
Methyl alcohol	2.5E+05	8.0E+01	2.9E+01	6.6E-01	3.5E-01
Methyl isobutyl ketone	1.1E+07	3.5E+03	1.3E+03	2.9E+01	1.5E+01
Methylene chloride	1.5E+07	4.8E+03	1.7E+03	4.0E+01	2.1E+01
Nickel	4.1E+03	1.3E+00	4.7E-01	1.1E-02	5.8E-03
Nitric acid	6.1E+07	2.0E+04	7.0E+03	1.6E+02	8.6E+01
Potassium chloride	9.1E+07	2.9E+04	1.0E+04	2.4E+02	1.3E+02
Potassium &chromate	3.0E+06	9.6E+02	3.4E+02	8.0E+00	4.2E+00
Potassium nitrate	2.4E+09	7.7E+05	2.7E+05	6.4E+03	3.4E+03
Potassium phosphate	1.3E+07	4.2E+03	1.5E+03	3.4E+01	1.8E+01
Potassium sulfate	9.1E+07	2.9E+04	1.0E+04	2.4E+02	1.3E+02
Silver	7.3E+03	2.3E+00	8.4E-01	1.9E-02	1.0E-02
Sodium	7.5E+04	2.4E+01	8.6E+00	2.0E-01	1.1E-01
Sodium chloride	1.8E+08	5.8E+04	2.1E+04	4.8E+02	2.5E+02
Sodium cyanide	1.9E+03	6.1E-01	2.2E-01	5.0E-03	2.7E-03
Sodium &chromate	5.4E+06	1.7E+03	6.2E+02	1.4E+01	7.6E+00
Sodium hydroxide	3.4E+02	1.1E-01	3.9E-02	9.0E-04	4.8E-04
Sodium nitrate	4.6E+09	1.5E+06	5.3E+05	1.2E+04	6.5E+03
Sodium phosphate	2.7E+07	8.7E+03	3.1E+03	7.2E+01	3.8E+01
Sodium potassium	2.3E+06	7.4E+02	2.6E+02	6.1E+00	3.2E+00
Sodium sulfate	2.1E+08	6.7E+04	2.4E+04	5.6E+02	2.9E+02
Sulfuric acid	1.5E+05	4.8E+01	1.7E+01	4.0E-01	2.1E-01
Terphenyl	1.0E+06	3.2E+02	1.1E+02	2.7E+00	1.4E+00
Tetrachloroethylene	9.8E+07	3.1E+04	1.1E+04	2.6E+02	1.4E+02
Toluene	2.5E+05	8.0E+01	2.9E+01	6.6E-01	3.5E-01
Tributyl phosphate	1.3E+06	4.2E+02	1.5E+02	3.4E+00	1.8E+00
Trichloroethylene	1.2E+08	3.9E+04	1.4E+04	3.2E+02	1.7E+02
Trimethylolpropane-tester	1.6E+06	5.1E+02	1.8E+02	4.2E+00	2.2E+00
Uranium	5.4E+08	1.7E+05	6.2E+04	1.4E+03	7.6E+02
Uranyl nitrate	2.8E+05	9.0E+01	3.2E+01	7.4E-01	3.9E-01
Versenes (EDTA)	1.4E+06	4.5E+02	1.6E+02	7.4E+01	3.1E+01
Xylene	9.8E+05	3.1E+02	1.1E+02	2.6E+00	1.4E+00
Zirconium	2.3E+07	7.4E+03	2.6E+03	6.1E+01	3.2E+01
Zirconium alloys	7.3E+06	2.3E+03	8.4E+02	1.9E+01	1.0E+01
Zirconium oxide	5.3E+03	1.7E+00	6.1E-01	1.4E-02	7.4E-03

Most of the organic chemicals found in RFP wastes are from organic setups. Organic setups (primarily 743 sludge) were produced from treatment of liquid organic wastes generated by various plutonium and nonplutonium operations at the RFP. The organic wastes were mixed with calcium silicate to form a grease- or paste-like material. Small amounts of Oil Dri (trade name) absorbent were usually mixed with the waste. Studies have been performed to determine the maximum quantity of carbon tetrachloride that could be present in a 743-sludge drum.[17] These studies show carbon tetrachloride quantity could be as high as 128 kg (20.9 gal); thus, for work specifically involving 743-sludge drums, this is considered the bounding quantity of carbon tetrachloride.

Large quantities of zirconium and zirconium alloy (technically considered a combustible metal) are buried at the SDA.

There is no evidence that ordnance or explicit explosives were buried at the SDA; however, oxidizers in the form of nitrates and dichromates, which can be explosive when mixed with oils, are present in the pits. There is little evidence that pyrophoric metals are buried at the SDA in a form that will either spontaneously ignite or be easily ignited and self-sustaining.

Based on experience with the stored waste inventory, hydrogen gas may be present due to radiological decomposition in wastes containing water or organic materials. It is believed that most of the metal drums will have corroded over 36 years of burial or were damaged during disposal to the point that they could not contain hydrogen gas; however, there is a remote possibility that some have maintained their integrity and could contain ignitable concentrations of hydrogen gas.

3.3.2.4 Hazard Categorization. The RWMC SDA had been designated as a Hazard Category 2 facility. Since this work is being performed in the SDA and involves intrusion into the waste, this activity is Hazard Category 2.

3.3.2.5 Hazard Evaluation. This section presents the results of the hazard evaluation performed using the methodology described in Section 3.3.1.2. Based on the hazards identified in Section 3.3.2.1, all the hazards determined to be significant (potential for a release of radioactive or hazardous material) or not routinely encountered are analyzed hrther.

3.3.2.3.1 Hazard Tab/ —The hazards considered for hrther evaluation are shown in Table 3-10 and include the following:

- Fissile material
- Ionizing radiation
- Radioactive material and nonradioactive hazardous (NRH) material
- Fire/explosion
- Natural Phenomena
- External Events.

Table 3-10. Hazards considered for evaluation.

					Likellhood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Identifier	Hazard	Hazardous Event	InitiatorICause	Applicable Facilities or Functions	Likellhood Category”	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
1(a)	Fissile material	Criticality	Concentration of fissile material and addition of moderator creates criticality event underground.	ISTD Treatment Area	Beyond Extreme1y Unllkely	Offsite public: N Collocated workers: N Facility workers: N Environment: L	1 1 1	See Chapter 6.	See Chapter 6
1(b)	Fissile material	Criticality	Migration of fissile material and addition of moderator creates criticality in vacuum heater piping system.	Vacuum heater well piping system	Beyond Extreme1y Unllkely	Offsite public: N Collocated workers: N Facility workers: M Environment: L	1 1 6	See Chapter 6.	See Chapter 6
1(c)	Fissile material	Criticality	Migration of fissile material and addition of moderator creates criticality in off-gas system.	Off-gas treatment system	Beyond Extreme1y Unllkely	Offsite public: N Collocated workers: N Facility workers: M Environment: L	1 1 6	See Chapter 6.	See Chapter 6
2(a)	Ionizing radiation	Excess worker dose from direct radiation	Drilling to install heater wells or moving soil cover exposes buried RH-LLW.	ISTD Treatment Area	Unllkely	Offsite public: N Collocated workers: N Facility workers: L Environment: N	4 4 8	Soil cover	Radiation Protection Program, Procedures, and training.
2(b)	Ionizing radiation	Excess worker dose from direct radiation	ISTD-induced subsidence exposes RH-LLW.	ISTD Treatment Area	Unllkely	Offsite public: N Collocated workers: N Facility workers: L Environment: N	4 4 8	Soil cover	Radiation Protection Program, Procedures, and training. Controls limiting heavy equipment operation above ISTD treated areas
3(a)	Radioactive and nonradioactive hazardous material	Underground explosion	Drilling into the waste to emplace the wells creates a drum explosion, chemical reaction, gas cylinder failure, or other energy release.	ISTD treatment areas	Extreme1y Unllkely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L Nonradioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: N	 2 5 9 2 5 9	Soil cover	Procedures and training. Radiation Protection Program. Emergency Preparedness Program

Table 3-10. (continued).

					Likellhood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Identifier	Hazard	Hazardous Event	InitiatorICause	Applicable Facilities or Functions	Likellhood Category”	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3(b)	Radioactive and nonradioactive hazardous material	Spread of contamination during well drilling or well completion.	Installing the wells will involve drilling into the waste and emplacing the wells. High levels of contamination could be encountered and brought to the surface.	ISTD treatment areas	Anticipated	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: N Nonradioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: N	 8 8 11 8 8 11	Soil cover Rotopercussion drill	Procedures and training Radiation Protection Program. Emergency Preparedness Program
3(c)	Radioactive and nonradioactive hazardous material	Release of radioactive or nonradioactive contaminants from an underground fire.	Heating the buried waste during ISTD treatment could ignite an underground fiie in the combustible materials.	ISTD treatment area	Unllkely	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L Nonradioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L	 4 4 8 4 4 8	Off-gas treatment system Soil cover Soil pressure monitors	Emergency Preparedness Program Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.
3(d)	Radioactive and nonradioactive hazardous material	Release of radioactive or nonradioactive contaminants from an underground explosion.	Heating the buried waste during ISTD treatment could ignite an underground explosion.	ISTD treatment area	Unllkely	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L Nonradioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L	 4 4 8 4 4 8	Off-gas treatment system Soil cover	Emergency Preparedness Program Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program.

Table 3-10. (continued).

Identifier	Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls: Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Preventive and Mitigative Controls: Design[d]	Administrative[e]
3(e)	Radioactive and nonradioactive hazardous material	Release of radioactive and nonradioactive contaminants from failed well header pipe.	Failure of well header piping from corrosion, explosion, fire, impacts, or other causes releases hazardous contaminants.	Well header piping	Unlikely	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L Nonradioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L	 4 4 8 - 4 4 8	Well header piping system Off-gas treatment system fans Sand filter in the vacuum/heater wells.	Emergency Preparedness Program. Radiation Protection Program. Industrial Hygiene Program. Industrial Safety Program
3(f)	Radioactive and nonradioactive hazardous material	Release of radioactive and nonradioactive contaminants from breach of the off-gas system.	Failure of the off-gas system from corrosion, explosion, fire, impacts, or other causes releases hazardous contaminants.	Off-gas treatment system	Unlikely	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L Nonradioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: L	 4 4 8 4 4 8 -	Off-gas treatment system design.	Emergency Preparedness Program Radiation Protection Program. Maintenance and inspection program. Procedures and training. Industrial Hygiene Program. Industrial Safety Program.
3(g)	Radioactive and nonradioactive hazardous material	Release of unprocessed off-gas containing radioactive and nonradioactive contaminants.	Operator error or equipment malfunction causes off-gases to be released directly to the environment without treatment by the off-gas treatment system.	Off-gas treatment system	Unlikely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L Nonradioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 4 8 ***12*** 4 8 12	***Off-gas treatment system.*** ***Off-gas treatment system stack monitor***	***Emergency Preparedness Program*** ***Radiation Protection Program*** ***Maintenance and inspection program*** Procedures and training. Industrial Hygiene Program. Industrial Safety Program.

Table 3-10. (continued).

					Likellhood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Identifier	Hazard	Hazardous Event	InitiatorlCause	Applicable Facilities or Functions	Likellhood Category”	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
3(h)	Radioactive and nonradioactive hazardous material	Release of radioactive and nonradioactive contaminants from positive pressure in the subsurface treatment area.	Equipment failure or loss of power causes the induced draft fan to fail, resulting in positive pressure in the entire ISTD system.	Off-gas treatment system, well header piping, vacuumheater wells, and ISTD treatment area.	Unllkely	Radioactive: Offsite public: N Collocated workers: N Facility workers: N Environment: N Nonradioactive: Offsite public: N Collocated workers: H Facility workers: H Environment: L	 *7* *7* *7* *7* ***15*** ***15*** 	***Redundantfans*** ***Standby diesel generator*** ***Off-gas treatment system*** Well header piping system ***Soil cover*** ***Soil pressure monitors***	***Emergency Preparedness Program*** ***Radiation Protection Program*** ***Maintenance and inspectionprogram*** Procedures and training. Industrial Hygiene Program. Industrial Safety Program.
3(i)	Radioactive and nonradioactive hazardous material	Release of radioactive and nonradioactive contaminants from an underground fiie that spreads beyond the treatment area.	Combustion processes that are part of the ISTD spread to areas beyond the area where off-gases are drawn into the off-gas treatment system.	SDA areas adjacent to ISTD treatment area.	Extremely unlikely	Radioactive: Offsite public: N Collocated workers: N Facility workers: L Environment: N Nonradioactive: Off-site public: N Collocated workers: N Facility workers: L Environment: N	 2 2 5 2 2 5 	Soil cover Location of heater and heaterlvacuum wells	Emergency Preparedness Program Radiation Protection Program.
4(a)	Firelexplosion	BLEVE	BLEVE from 6,000-gal propane supply tank due to any initiatorlcause breaches the off-gas treatment system.	Propane tank trailer Off-gas treatment system.	Unllkely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: N Nonradioactive: Off-site public: N Collocated workers: L Facility workers: M Environment: L	 4 8 ***12*** 4 8 ***12*** 	***Off-gas treatment system*** ***Propane system designed to NFPA 58***	***Emergency Preparedness, Fire protection program***, ***Proceduresfor monitoring and maintenance of the propane system,*** training.

Table 3-10. (continued).

					Likellhood, Consequence, and Risk Without Controls			Preventive and mtigative Controls	
Identifier	Hazard	Hazardous Event	InitiatorlCause	Applicable Facilities or Functions	Likellhood Category"	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
4(b)	Firelexplosion	Fuel-air explosion.	Leak or rupture in propane feed line or the thermal oxidizer causes a propane fire or explosion, which breaches the off-gas system.	Off-gas treatment system.	Unllkely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: N Nonradioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 4 8 ***12*** 4 8 ***12***	Propane detectors and alarm. ***Propane system designed to NFPA 58***	***Emergency Preparedness, Fire protection program, Proceduresfor monitoring and maintenance of the propane system, training.***
4(c)	Firelexplosion	Surface fiie in the ISTD area.	Fire in the ISTD area caused by brush fiie, vehicle fuels, propane, welding and cutting, or other causes.	Off-gas treatment system Well header piping.	Unllkely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: N Nonradioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 4 8 ***12*** 4 8 ***12***	Off-gas treatment system ***Propane system designed to NFPA 58***	***Emergency Preparedness, Fire protection program, Proceduresfor monitoring and maintenance of the propane system, training.***
5(a)	Natural phenomena	Lightning	Lightning causes failure of the induced draft fan, the off-gas system or the well header piping.	Off-gas treatment system, well header piping.	Unllkely	Radioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L Nonradioactive: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 f f f f f f f f	Backup power for off-gas system. Design and construction of the off-gas system and piping (lightning protection).	Fire Protection Program. Emergency Preparedness Program. Procedures and training.
5(b)	Natural phenomena	Volcanic Activity	Lava flow encroaches upon ISTD activities.	ISTD treatment area well header piping off-gas treatment system	Extremely Unllkely	Offsite public: N Collocated workers: L Facility workers: M Environment: N	f f f f		Advance notice provides time to secure facilities, and possibly take some mitigating emergency action. Emergency Preparedness Program

Table 3-10. (continued).

					Likellhood, Consequence, and Risk Without Controls			Preventive and mtigative Controls	
Identifier	Hazard	Hazardous Event	InitiatorICause	Applicable Facilities or Functions	Likellhood Category"	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]
5(c)	Natural phenomena	Flood	Flooding occurs as a result of surface water runoff or flooding bodies of water surrounding the RWMC.	ISTD treatment area.	Unllkely	Offsite public: N Collocated workers: N Facility workers: N Environment: N	f f f f	Soil cover INEEL and SDA flood control system design and maintenance.	Monitoring of meteorological conditions. Procedures for maintenance and inspection of culverts, dikes, and drainage channels. Emergency Preparedness Program.
5(d)	Natural phenomena	Earthquake	An earthquake results in a loss of power, damages the off-gas system or well header piping, or initiates significant subsidence.	ISTD treatment area well header piping off-gas treatment system.	Unllkely	Offsite public: N Collocated workers: L Facility workers: M Environment: L	f f f f	Soil cover Backup power Design and construction of the well header piping and off-gas treatment system	Radiation protection program Maintenance and inspection program Fire Protection Program. Emergency Preparedness Program.
5(e)	Natural phenomena	High wind	High winds and wind borne missiles damage the off-gas system, the well header piping, or create a loss of power.	Well header piping off-gas treatment system	Unllkely	Offsite public: N Collocated workers: L Facility workers: M Environment: L	f f f f	Backup power Design and construction of the well header piping and off-gas treatment system.	Monitoring of meteorological conditions. Operating procedures. Emergency Preparedness Program.
5(f)	Natural phenomena	Extreme snow load	Snow load damages the off-gas treatment system or the well header piping.	ISTD treatment area well header piping off-gas treatment system	Unllkely	Offsite public: N Collocated workers: N Facility workers: N Environment: N	f f f f	Backup power for off-gas treatment system. Design and construction of the well header piping and off-gas treatment system. Process heat.	Remote operations. Monitoring of meteorological conditions. Operating procedures. Emergency Preparedness Program.

Table 3-10. (continued).

Identifier	Hazard	Hazardous Event	InitiatorlCause	Applicable Facilities or Functions	Likellhood, Consequence, and Risk Without Controls: Likellhood Category"	Consequence Category[b]	Risk Bin Number[c]	Preventive and mtigative Controls: Design[d]	Administrative[e]
6(a)	External events	Accident in collocated facility	Any initiatorlcause of an accident in a collocated facility.	ISTD Treatment Area	Unllkely	Offsite public: N Collocated workers: N Facility workers: N Environment: N	4 4 4	Confinement provided by collocated facility.	Emergency notification and response systems. Fire Protection Program. Radiation Protection Program. Industrial Hygiene Program.
6(b)	External events	Loss of offsite power	Due to any initiatorlcause, the offsite power supply is interrupted.	Off-gas treatment system ISTD heaters	Anticipated	<u>Radioactive</u>: Offsite public: N Collocated workers: L Facility workers: M Environment: L <u>Nonradioactive</u>: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 7 11 ***14*** 7 11 14	***Standby diesel generator***	***Radiation Protection Program*** ***Emergency Preparedness Program Maintenance and inspection program*** Procedures and training.
6(c)	External events	Aircraft impact	An aircraft flying over the RWMC area crashes and damages the ISTD system.	ISTD treatment area Well header piping Off-gas treatment system	Beyond Extremely Unllkely	Offsite public: L Collocated workers: H Facility workers: H Environment: M	3 10 10 -		Flight frequency is minimal over the RWMC. Emergency Preparedness Program Fire Protection Program.
6(d)	External events	Range fire	Range fire crosses into the SDA and causes failure of the well header piping or gas treatment system.	Well header piping Off-gas treatment system	Unllkely	<u>Radioactive</u>: Offsite public: N Collocated workers: L Facility workers: M Environment: L <u>Nonradioactive</u>: Offsite public: N Collocated workers: L Facility workers: M Environment: L	 4 8 ***12*** 4 8 12	***Well header piping system*** ***Off-gas treatment systemfans*** Sand filter in the vacuum/ heater wells.	***Emergency Preparedness Program*** ***Radiation Protection Program*** Industrial Hygiene Program. Industrial Safety Program

Table 3-10. (continued).

					Likelihood, Consequence, and Risk Without Controls			Preventive and Mitigative Controls	
Identifier	Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category[a]	Consequence Category[b]	Risk Bin Number[c]	Design[d]	Administrative[e]

a. The likelihood categories are listed and described in Table **3-1**.
b. The consequence categories are denoted with the following: N – negligible, L – low, M – moderate, and H – high and are described in Table **3-2**.
c. Risk bin numbers are highlighted in bold italics if they indicate that safety SSCs and/or TSRs should be identified to manage risk (see Figures **3-1, 3-2,** and **3-3).**
d. SSCs designated as safety-class or safety-significant SSCs are highlighted in bold italics. See Chapter 4 for information on these safety SSCs.
e. Technical Safety Requirement level controls are highlighted in bold italics. See Chapter 5 for information on TSRs.
f. Natural phenomena hazard initiated events are not assigned risk bin numbers. See discussion for each of the natural phenomena hazards.

BLEVE	boiling liquid-expansion vapor explosion	PPE	personal protective equipment
HEPA	high-efficiency particulate air	RWMC	Radioactive Waste Management Complex
INEEL	Idaho National Engineering and Environmental Laboratory	SDA	Subsurface Disposal Area
ISTD	in situ thermal desorption	SSC	structure, system, and component
NFPA	National Fire Protection Association		

Qualitative estimates for the likelihood and consequences from releases of radioactive and nonradioactive hazardous materials are shown. The categorization of likelihood, consequence, and risk are based upon the criteria provided in Section 3.3.1.2. The likelihood, consequence, and risk categorization are based upon unmitigated events (that is, without preventive or mitigative controls). Table 3-10 also lists possible design and administrative barriers to the occurrences. When warranted by the risk bin, safety-class SSCs, safety-significant SSCs, and TSRs are identified in ***bold italics.***

As shown in Table 3-10, for all hazardous scenarios where the estimated risk could exceed established evaluation guidelines (that is, risk bins in the shaded area of Figures 3-1, 3-2, and 3-3), safety SSCs or TSRs are designated or identified to reduce the risk below the INEEL risk evaluation guidelines from DOE-ID Order 420.D.

Each of the hazardous events and initiators/causes in Table 3-10 is discussed in the following paragraphs. The alphanumeric identifiers provide the cross-reference to Table 3-10.

1 (a) Criticality in the ISTD treatment area

For a criticality to occur underground in the treatment area, fissile material that is dispersed, mixed with dirt and other materials, and normally dry, would have to be relocated and concentrated as a result of ISTD processes or some other cause. In addition, sufficient moderator, such as floodwater, would have to be added in the optimum geometrical configuration. Because the criticality would occur underground, the consequences would be negligible for the facility worker. The probability that this material would concentrate and be moderated in the correct geometry is judged to be beyond extremely unlikely. Criticality events are addressed in greater detail in Chapter 6 and are only included here for completeness.

1 (b) Criticality in the vacuum heater well piping

Fissile material would migrate through the ground and sand filter with the off-gas and concentrate in the well piping. Through flooding with water or some other mechanism, moderator would be added to the piping in the correct geometry and create a criticality. Because the criticality would occur aboveground where workers are present, the consequences would be moderate. The probability that this material could concentrate and be moderated in the correct geometry is judged to be beyond extremely unlikely. Criticality events are addressed in greater detail in Section 6 and are only included here for completeness.

1 (c) Criticality in the off-gas system

Fissile material could migrate through the ground and sand filter with the off-gas and concentrate in the off-gas system. This would most likely occur upstream in the cyclone separator or HEPA filter. Through flooding with water or some other mechanism, moderator would be added to the off-gas system creating a criticality. Because the criticality would occur aboveground where workers are present, the consequences would be moderate. The probability that this material could concentrate and be moderated in the correct geometry is judged to be beyond extremely unlikely. Criticality events are addressed in greater detail in Section 6 and are only included here for completeness.

2 (a) Exposure to high radiation levels during well installation or excavation

The SDA contains RH-LLW with surface radiation exposure rates up to 24,000 R per hour. The soil cover normally shields the radiation. Emplacing the wells or moving soil cover could expose a source, create a radiation streaming path to the surface, or induce subsidence, exposing workers to an unshielded direct radiation source. The unmitigated consequences to a facility worker are estimated as low for an unlikely event with a source below 1,000 R/hr and high for an extremely unlikely event with a source of 24,000 R/hr. Although subsidence is common, no subsidences have exposed high radiation sources.

2 (b) Exposure to high radiation levels from SDA subsidence

The SDA contains RH-LLW with surface radiation dose rates up to 24,000 R per hour. The soil cover shields the radiation. The ISTD process will create large voids beneath the surface as materials are melted or consumed. These large voids could induce subsidence, causing workers to be exposed to an unshielded direct radiation source. The unmitigated consequences to a facility worker are estimated as low for an unlikely event with a source below 1,000 R/hr and high for an extremely unlikely event with a source of 24,000 R/hr. Although subsidence is common, no subsidences have exposed high radiation sources.

3 (a) Drilling initiated underground explosion

Holes will be drilled into the waste for the heater wells and vacuum/heater wells. Drilling into the waste could create an energy release by igniting radiolytically generated hydrogen trapped in a drum, causing chemical reactions among buried waste constituents, or penetrating a disposed pressurized gas cylinder. This phenomenon was investigated for the GEM Project at Pit 9 and the probability was determined to be extremely unlikely.[18,19] An underground explosion could release radioactive and nonradioactive hazardous materials into the air. For the unmitigated case, which assumes limited effectiveness of the soil cover, the consequences are estimated to be moderate for the facility worker.

3 (b) Well installation creates high contamination

Placing the wells in the ISTD treatment area will require drilling holes, placing wells down the holes, and finishing the wells. Drilling will require bringing the drill to the surface after the hole is drilled. Placing and finishing the wells could bring materials to the surface. All these activities are anticipated to bring up small quantities of contamination. It also creates the potential that unusually high levels of radioactive or nonradioactive hazardous contamination could be encountered and brought to the surface. The consequences are expected to be low for the facility worker and negligible downwind.

3 (c) Underground fire

In situ thermal desorption processing will involve heating buried waste to temperatures approaching 1,500°F. Flammable and combustible materials in the waste include wood, rags, organic sludges, graphite, and other materials. The ISTG system is designed to destroy these materials and process the combustion products through the off-gas system; however there is a potential for an underground fire that consumes combustible materials and, for the unmitigated scenario, releases the combustion products and entrained contaminants directly to the environment.

A fire could result from the accumulation of a flammable mixture of hydrogen plus an ignition source. Some TRU waste buried in the SDA has the potential for generating explosive mixtures of hydrogen gas. The possible mechanisms for gas generation in TRU waste include radiolysis, thermal degradation, bacteriological decomposition, chemical corrosion, and alpha decay. Only radiolysis has been observed to produce H_2.[20] Mixtures of 4.0 to 75% H_2 by volume in air (a minimum of 5% O_2 must be present in the air) can be flammable.[21]

There is little evidence that pyrophoric metals are buried at the SDA in a form that either will spontaneously ignite or be easily ignited and self-sustaining. The Series 741 through 745 sludges contain a precipitate of magnesium oxide, but in this state, it is not ignitable. Sodium and potassium are buried in the SDA, but as part of compounds, not as distinct pyrophoric metals. There may be some lithium batteries in 742 sludge drums. These batteries may be a combustible threat if intact and then punctured, but they are a small energy source and easily contained. Aluminum and iron are buried in the SDA; but they are not combustible when in a massive form. Large quantities of zirconium and zirconium alloy that are technically considered combustible metals are buried at the SDA, but the combustibility of zirconium decreases as the average particle size increases. As large bars, narrow plates, and long strips, zirconium can withstand extremely high temperatures without igniting. Spontaneous ignition or explosions of zirconium during handling are not likely unless the metal is very finely divided. Zirconium fines in the 3-micron size will ignite at room temperature and fines in the 6-micron size will ignite at approximately 374°F; however, any fines that may be present in the SDA have likely oxidized during 36 years of being exposed to the elements and no longer present a pyrophoric hazard.

The surface of uranium contaminants would likely be oxidized and not be metallic pyrophoric powder. A condition that reduces the fire hazard by this source is that the waste form containing the uranium is sludge. The general form of the waste matrix is a slurry comprised of 50–70 wt% water when packaged.[22] In the process of forming the sludge, the uranium contaminants would be dispersed in the material and this dispersion would act as a barrier to fire propagation.

Beryllium (although not pyrophoric) when in dust or flake form and mixed with carbon tetrachloride, trichloroethane, or trichloroethylene will form flammable gases that can spark or flash. For beryllium in sludge form,[22] the same argument used for uranium would apply. As large blocks, beryllium is not likely to form flammable gases.

Nitrocellulose is a highly flammable solid that may be found in a highly impure form and limited quantities in the SDA. Nitrocellulose is capable of spontaneous ignition, particularly when dry. Based on an evaluation of waste streams and factors that must be in place to form nitrocellulose, nitrocellulose formation is highly improbable; thus, Einerson and Thomas[23] conclude that the nitrocellulose quantity is estimated as zero for Pit 9. The conclusion that the nitrocellulose quantity in Pit 9 is zero is based on an analysis of RFP waste.[24] Since the majority of the waste to be treated with ISTD is from RFP, this same estimation can be made for the SDA as a whole.

Mitigating features include complete effectiveness of the soil cover and the off-gas treatment system. This scenario is estimated to be unlikely. Consequences are estimated to be low to the facility worker, negligible to the collocated worker, and negligible to an offsite receptor.

3 (d) Underground explosion

In situ thermal desorption processing will involve heating buried waste to temperatures approaching 1,500°F. Research and testing have shown a potential for nitrate salts mixed with oil, charcoal, graphite, and cellulosic materials to undergo deflagration or similar explosive reactions when heated at high heating rates of 100°C per hour.[7] In situ thermal desorption will be heated at much lower heating rates, but the potential for explosions to occur cannot be dismissed.

Another potential source for an underground explosion is hydrogen. Based on experience with the stored waste inventory, hydrogen gas may be present in waste containing water or organic materials because of radiolysis. This gas will disperse over time through any polyethylene bags; however, it could be contained in unvented sealed drums that are still in good condition. Most of the buried metal drums are believed to have corroded to the point where they will not contain hydrogen gas. This belief is hrther supported by recent observations through visual probes in OU 7-10 that indicate drums to be completely corroded away.

An evaluation was performed on the generation and retention of methane and hydrogen gases because of microbial activity on the waste zone materials. This evaluation involved collecting gas samples from Pit 10, which is representative of OU 7-10, and performing an analysis of the potential for methane and hydrogen gas generation.[25] This analysis concludes that (1) very little methane or hydrogen gas is produced and retained because high concentrations of polychlorinated hydrocarbons are microbial poisons, (2) even under the most conservative conditions, the methane oxidation rate and the methane generation rate are almost identical, and *(3)* methane and hydrogen gas diffuse through the overburden.

The probability for such an event is judged to be unlikely. The ISTD process is intended to destroy the potential explosive materials through a controlled underground process, with heating at a slow rate. The consequences are estimated to be low to the facility worker, negligible to the collocated worker, and negligible to an offsite receptor. Complete effectiveness of the soil cover is a mitigating feature.

3 (e) Well header piping failure

The well header piping routes air and combustion gases from the underground ISTD treatment area individual vacuudheater wells to common headers and then to the off-gas treatment system. The gases may be contaminated with radioactive and NRH materials extracted from the treatment zone and passed through the sand filters in the vacuudheater wells. Corrosion, explosion, fire, subsidence, or impacts from external objects such as vehicles or cranes could breach the piping. The gases are maintained at high temperature to prevent condensation of hydrocarbons that could mix with water and form acids that attack the piping. The piping will normally be maintained at negative pressure, so a small failure would result in in-leakage rather then releases; however, large breaches combined with a loss of the induced draft fans could result in releases. This event is estimated to be unlikely, with low consequences to the facility worker, negligible to the collocated worker, and negligible to the offsite receptor.

3 (f) Off-gas system breach

The off-gas system consists of a cyclone separator, HEPA filters, thermal oxidizer, heat exchanger, dry scrubber, carbon bed adsorbers, and induced draft fan. The system is fully enclosed and operates at a negative pressure. Internal explosions, fire, corrosion, subsidence, and impacts from external objects such as vehicles or cranes could breach the off-gas system. The system will normally be maintained at negative pressure, so a small failure would result in in-leakage rather then releases; however, large breaches combined with a loss of the induced draft fans could result in releases. This event is estimated to be unlikely, with low consequences to the facility worker, negligible to the collocated worker, and negligible to the offsite receptor.

3 (g) Off-gas system failure

The off-gas system uses induced draft fans to draw air through the buried waste, into the heaterhacuum wells and well header piping, then into the off-gas system for removal of contaminants before discharging the treated gas to the environment. An undefined equipment failure or operator error could lead to bypassing or ineffective operation of the off-gas treatment system. This would result in discharging untreated air to the environment. This event is estimated to be unlikely, with moderate consequences to the facility worker, low to the collocated worker, and negligible to the offsite receptor.

3 (h) Positive pressure from induced draft fan failure

The induced draft fan in the off-gas system maintains a negative pressure throughout the ISTD system. This is important for several reasons. It draws air into the waste treatment zone allowing treatment to proceed. It also draws air through the sand filters and into the vacuudheater wells allowing the sand filters to remove contaminants from the gas stream. It maintains negative pressure in the well header piping and off-gas treatment system so that if breaches occur, the contaminants will be drawn through the off-gas system rather than being released. The fan could fail from loss of power, mechanical breakdown, or natural events. Failure of the fan could cause positive pressure in the subsurface, thereby releasing contaminants to the environment through the soil, particularly if no credit is taken for the 10-ft overburden as a mitigative feature. It could also contribute to failure of the well header piping and off-gas systems and cause releases to the environment. This event is considered unlikely, with high consequences to the facility worker and collocated worker, and negligible to the offsite receptor.

3(i) Underground fire beyond the treatment area

Since ISTD creates underground combustion or oxidation processes, a fire could be initiated that spreads beyond the treatment area where the processing products are drawn into the off-gas treatment system. This could result in hazardous materials being released directly to the environment. Such an event is extremely unlikely because beyond the treatment area there is no heat source from the heater wells and no oxygen source other than infiltration from above to sustain such a fire. The soil above and mixed with the waste will prevent air infiltration. Also, the overburden will limit transport of hazardous materials to the surface; thus, this event is extremely unlikely and would have low consequences.

4(a) Fire/explosions — Propane tank fire/BLEVE

A BLEVE could occur at the trailer-mounted 6,000-gal propane supply tank, which will be located near the off-gas treatment system. This event could initiate an off-gas treatment system failure as discussed above. The resulting fire could also seriously burn or kill facility workers; thus, the consequences of this event are moderate to the facility worker, low to the collocated worker, and negligible to the off-site receptor. This event is unlikely.

4(b) Fire/explosions — Fuel-air explosion

A fuel-air explosion could occur in the off-gas treatment system area from a leak or rupture in the propane line from the propane tank to the thermal oxidizer or in the oxidizer. This event could initiate an off-gas treatment system failure as discussed above. The resulting fire could also seriously burn or kill facility workers; thus, the consequences of this event are moderate to the facility worker, low to the collocated worker, and negligible to the offsite receptor. This event is unlikely.

4(c) Fire/explosions — Surface fire in the ISTD area

Combustion sources such as leaking vehicle fuels, propane, welding and cutting activities, and brush fires could cause a surface fire that damages the ISTD system. This event could initiate an off-gas treatment system breach as discussed above; thus, the consequences of this event are moderate to the facility worker, low to the collocated worker, and negligible to the off-site receptor. Although fires are anticipated, a fire severe enough to breach the ISTD system is unlikely.

5 Natural Events

The assessments of lightning strike, volcanic eruption, flood, earthquake, high winds, and snow loading are based on the potential energies and potential for a release. The bases for the consequence assessments are found in the RWMC SAR. Some scenarios have the potential for moderate environmental damage because of the potential for spreading contamination over a large area.

Safety-significant SSCs and SSCs that perform emergency hnctions to preserve the health and safety of the workers are generally classified as Performance Category (PC)-2 in accordance with DOE Standard (DOE-STD)-1021-93, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components."[26] The natural event hazard probabilities associated with design goals for PC-2 SSCs are (1) 1E-03 for earthquake and (2) 2E-02 for wind.[27] The PC-2 criteria for flooding are beyond design basis for this project. The INEEL volcanism working group[28] and Hackett and Smith[29] estimated the conditional probability of basaltic volcanism to affect a south-central INEEL site as being less than 1E-05 per year. Lightning strikes and snow-loading scenarios are credible scenarios for the RWMC and project facility operations.

5(a) Lightning Strike

Lightning strikes are classified into two categories: (1) a cold strike in which the return strike is of short duration and has a mechanical or explosive effect that tends to shatter and strip bark from trees and rip clothing from human victims and (2) a hot strike where the current is of longer duration that tends to start fires. The probability that a lightning strike is a cold or hot strike is 0.5.[26] The accident analysis is concerned with both types of strikes because of the potential to start a fire or damage equipment. The following equation is used to determine the frequency of lightning strikes:

Frequency strike = strikes/year/mi^2 x facility area mi^2

The number of strikes per year per square mile can be determined based on readings from lightning strike detection field instruments operated by the Bureau of Land Management of the National Interagency Fire Center. From 1985 to 2000, the Bureau of Land Management instruments recorded 76 lightning strikes in the 5-mi^2 area around the RWMC.[30] None of the strikes was in the SDA. The number of lightning strikes per year per square mile is 76 strikes/15 years/5 mi^2 or 1 strike/year/mi^2. The ISTD treatment area is 2.6 acres or approximately 4.1E-03 mi^2; therefore, the frequency of a hot strike on an ISTD treatment area is approximately 4.1E-05/year, which is within the unlikely range of occurrences. The consequences of this event to facility workers and collocated workers are categorized as moderate and low, respectively. This is based upon the potential to damage the ISTG equipment or start a fire. The ISTG equipment will have lightning protection to prevent this scenario.

5(b) Volcanic Activity

Volcanic activity has occurred in the area in the geologically recent past and could occur again. The consequences of a lava flow are similar to those for failure of the off-gas system or wellhead piping, since these are the likely consequences of volcanism. Volcanism is not expected to affect the buried waste other than possibly to cover it over with lava. Advance notice may provide sufficient time to divert the flow or secure the facilities. A lava flow is categorized as extremely unlikely (see Chapter 1, SAR-100)

5(c) Flooding

Flooding scenarios are initiated by natural events such as heavy rain and snowmelt. Floods have previously occurred at the SDA. The consequences to workers and collocated workers are categorized as negligible since there were no consequences resulting from previous flooding of the SDA. Advance notice would provide sufficient time to secure the facilities. The 100-yr flood does not approach the RWMC, and hence is not a relevant scenario. The 10,000-yr flood and the Mackay Dam failure would both reach the SDA. These events are categorized as unlikely. There are two existing diversion dikes that are assumed to fail for the Mackay Dam failure.

The flood control design and flood control maintenance program provide preventive and mitigative measures. There is an existing dike around the SDA that would prevent either flood from impacting the radioactive materials. Some overtopping may occur in the southwest corner of the SDA dike during the Mackay Dam flood. Improvements have been made to the dikes and RWMC drainage system to protect aboveground waste against a credible flood.

5(d) Earthquake

A design basis earthquake can result in the initiation of subsidence, equipment damage, and fires, which can result in the release of radioactive and hazardous material. The consequences of this event to workers and collocated workers are categorized as moderate for facility workers and low for collocated workers. A design basis earthquake is categorized as unlikely. The well header piping, off-gas treatment system, and power supply should be seismically qualified and meet or exceed Seismic Zone 2 standards.

5(e) High Wind

High winds have the potential to result directly in personnel injury and death. High winds can also damage the ISTD equipment and initiate fires. The consequences of this event to workers and collocated workers are categorized as moderate for facility workers and low for collocated workers. High winds are categorized as unlikely. The consequences and controls associated with tornadoes are similar to those for high winds. DOE-1020-2002 and SAR-100 state that, for the INEEL, tornados are not to be considered in the design of nuclear facilities. Monitoring of meteorological conditions, procedures, and the Emergency Preparedness Program would reduce the likelihood and consequences of high-wind initiated events.

5(f) Snow Loading

Although extremely heavy snowfall is possible, it should not damage the ISTD equipment or affect the ISTD treatment area. The consequences and controls associated with extreme snow loads are negligible for all receptors. The process heat should help keep the equipment free from snow and monitoring of meteorological conditions allow sufficient time to secure the equipment.

6 External events

6(a) Accidents in a collocated facility

Nearby facilities with hazards that could affect ISTD at the SDA include the Advanced Mixed Waste Treatment Facility, Transuranic Storage Area, and other parts of the Subsurface Disposal area, which are all at the RWMC; other INEEL facilities; and offsite facilities. All these facilities are sufficiently isolated from ISTD that an event at these facilities will not trigger hrther events at ISTD. The risk to ISTD workers from other facilities is the airborne spread of radioactive or nonradioactive hazardous substances. The frequency and consequence depend on the specific accident. Any event releasing such materials would trigger the emergency notification system and appropriate actions would be taken to protect workers.

6(b) Loss of offsite power

A loss of offsite power could initiate an induced draft fan failure accident in the off-gas treatment system, causing positive pressure in the ISTD treatment area with the same consequences as discussed above. Loss of offsite power would also cut power to the heaters in the ISTD wells and stop heating and ISTD processing. This would occur slowly and have no safety impact. Loss of offsite power is an anticipated event.

6(c) Airplane crashes into the ISTD area

An airplane crash into the ISTD area would breach the ISTD equipment, including any or all of the off-gas treatment system, the well header piping, and the ISTD wells. An extremely severe crash could also cause releases from the buried waste. Releases would include radioactive and nonradioactive hazardous materials. Because such a scenario would be highly energetic, the consequences are estimated to be high for the facility and collocated workers, and low for offsite individuals. This event is beyond extremely unlikely.

6(d) Range Fires

Range fires have occurred at the INEEL and are anticipated; however, a range fire severe enough to penetrate into the SDA and damage the ISTD area is unlikely. If it did, the waste would remain beneath the surface. A severe range fire is one of the initiators for the fire and BLEVE scenarios previously discussed, and the consequences of this event are categorized as moderate for facility workers, low for collocated workers, and negligible for offsite receptors.

3.3.2.5.1 Planned Design and Operational Safety Improvements — The design includes the necessary safety features to ensure worker safety. The hazard evaluation does not identify the need for improvements to the design of project facilities or operational safety.

3.3.2.5.2 Defense-in-depth — The defense-in-depth approach builds in levels of safety so that no one level, no matter how good, is completely relied on. The first level of safety is the design of **SSCs** or administrative controls to ensure that hazards are safely contained. The second level is the automatic alarms and detection systems if the first level fails and an accident initiates. The third level is mitigation (such as secondary confinement, personal protective equipment [PPE], and the Emergency Preparedness Program).

Each of the three levels of the defense-in-depth approach to overall safety applies to hazards identified in Table 3-10. The intent is to identify the broad purpose and importance of defense-in-depth features, not the details of their design or implementation. Table 3-11 identifies these features in a broad sense.

Table 3-11. Defense-in-depth features.

Hazard	First Level	Second Level	Third Level
Criticality	Waste acceptance, procedures, criticality safety evaluation, training	Not required	Emergency responselevacuation
Ionizing radiation	Soil cover	Alarmslradiation detection	Emergency responselevacuation
Radioactive and nonradioactive hazardous material	Soil cover, system design, radiation protection program, minimum staffing, procedures, training, fire protection system	Alarms/detection, soil pressure monitors	Emergency responselevacuation
Firelexplosion	Soil cover, system design, fire protection program, procedures, training	Fire alarm system, soil pressure monitors	Emergency responselevacuation
Natural phenomena	System design, training	Monitoring environmental conditions (such as weather and seismic)	Emergency response
External events	Soil cover, system design	Alarmslradiation detection. fire alarms	Emergency notification and response

Safety-Significant SSCs. As required by DOE-STD 3009-94, part of the defense-in-depth is to identify those **SSCs** that are safety-significant. The safety-significant **SSCs** for ISTD are listed in Table 3-12, where they are designated as passive or active.

Table 3-12. Safetv significant **SSCs** for ISTD.

SS SSC	Passive/Active	Hazard
Off-gas treatment system	Active	Hazardous material releases from an off-gas system breach or release without treatment.
Off-gas treatment system induced draft fans	Active	Hazardous material releases from the buried waste caused by positive pressure in the off-gas treatment system
Standby diesel generator	Active	Hazardous material releases from the buried waste or system breaches caused by positive pressure in the off-gas treatment system, resulting from loss of electrical power causing fans failure.
Off-gas treatment stack monitoring system	Active	Hazardous material releases from failure of the off-gas system to remove contaminants from the off-gas stream
Soil pressure monitors	Active	Radionuclides and NRH materials released by positive pressure in the treatment area

Technical Safety Requirements. This section summarizes those safety-significant **SSCs** and other aspects of defense-in-depth that will be provided technical safety requirement coverage. Features designated for TSR coverage are listed in Table 3-13.

3.3.2.5.3 Worker Safety — The INEEL's Integrated Safety Management System ensures that safety is considered in all aspects of operations and maintenance, and is hlly integrated into planning and performing work process. The safety-significant **SSCs** and TSRs also enhance worker safety. Features that help ensure worker safety include safety systems, procedures, reviews and audits, emergency preparedness programs, configuration management, quality assurance, occurrence reporting and lessons learned, qualification and training, and the required safety management programs.

3.3.2.5.4 Environmental Protection — The hazard evaluation shows that impacts to the environment resulting from ISTD operations will be minor. Gaseous materials generated through the ISTD process beneath the surface will be drawn into the heater/vacuum wells and processed through the off-gas treatment system. The off-gas system consists of high temperature particulate filters to remove particulate, thermal oxidation units to remove trace organics, dry scrubbers to remove acid gases, and activated carbon adsorbers to remove any remaining contaminants. The off-gas treatment train is designed to achieve a total of 99.9999% destruction efficiency and to meet all applicable permit requirements. No effluents are expected to be released through the soil cover or bypass the off-gas system under normal conditions. The exhaust stream from the off-gas trailer exhaust flow will be monitored continuously for the release of hydrocarbons and radionuclides.

Table 3-13. Hazard protection features requiring TSR coverage.

Maior Protection Features	TSR	Hazards
Off-gas treatment system, including induced draft fans and stack monitoring system are safety-significant SSC.	Verify operability and condition of off-gas treatment system, fans, and stack monitoring Maintenance and inspection program radiation protection program	Releases from treatment area caused by positive pressure in the off-gas treatment system Releases from off-gas treatment system caused by breach Releases from off-gas treatment system caused by its failure to remove contaminants.
Standby diesel generator is safety-significant SSC.	Verify operability and condition of standby diesel generator Maintenance and inspection program	Hazardous material releases from the buried waste or system breaches caused by positive pressure in the off-gas treatment system resulting from loss of electrical power causing fans failure.
Soil cover	Establish and maintain soil cover depth Control heavy equipment access to ISTD treated areas subject to subsidence Radiation protection program	Direct radiation from buried RH LLW Releases emanating from the ISTD treatment area Drilling into waste during well emplacement. Subsidence caused release Flooding Earthquake.
Soil pressure monitors	Verify operability of the soil pressure monitors	Radionuclides and NRH materials released by positive pressure in the treatment area.
Respond to emergencies to protect workers and safety significant SSCs	Emergency preparedness program Procedures and training	Any accident at the ISTD treatment area, from natural phenomena or from external events.
Fire protection	Fire protection program Propane system designed to meet NFPA-58	Fire ignited from ISTD system, natural phenomena, or from external sources BLEVE, fire, or explosion from the propane tank.

The radiation program Will eventually be removed from the TSR document because it is required by 10 CFR 835, Occupational Radiation Protection.[31]

3.3.2.5.5 Accident ***Selection—***The hazard evaluation in Table 3-10 shows the highest hazards are from releases of radioactive and NRH materials that would be generated through an accident in the ISTD treatment area and failures in the ISTD system. Detailed accident analyses will be performed to assess the consequences of the hypothetical accidents shown below. These accidents were selected to envelope the complete range of potential accidents during ISTD processing.

- Uncovering a high-radiation source—determines potential consequences from direct radiation exposure to a high-radiation package beneath the SDA surface.

- Underground drum explosion—determines potential consequences from a fire or explosion in a single drum that expels material to the surface, without taking credit for the mitigating affects of the additional soil cover.

- Well header piping failure—bounds the consequences for a breach-type accident in the well header piping or off-gas system that causes immediate release of the contents.

- Off-gas system failure—bounds the consequences of an accident where ISTD processing continues, but the waste gases are not treated by the off-gas system.

- Positive pressure in the subsurface treatment area—bounds the consequences of an accident where hazardous materials escape from the ground before they are drawn into the off-gas well header piping. Potential causes are an underground fire or positive off-gas pressure causes by fan failure or other similar events.

3.4 Accident Analysis

This section analyses the accidents selected in Section 3.3 through the hazard analysis process These are bounding accidents that will be used to establish the safety controls. In accordance with direction in DOE-STD-3009-94, exposures to the facility workers have been qualitatively assessed. Equipment that is safety-significantto facility workers has been determined in Table 3-10.

3.4.1 Methodology

The source term for the accidents that release hazardous material were calculated using the following source term equation recommended by DOE-STD-30 10-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities:[32]

ST = MAR x DR x ARF x RF x LPF

where

ST	=	source term (Ci)
MAR	=	material at risk (Ci)
DR	=	damage ratio
ARF	=	airborne release fraction
RF	=	respirable fraction
LPF	=	leak path factor.

Material at risk. Information about the quantities of radioactive materials buried in the SDA is in Section 3.3.2.1.2. The MAR for a particular accident is a subset of the entire inventory that is determined based on the nature of the accident and the intent of the analysis. The MAR for each accident is determined in the appropriate section.

Damage Ratio. The damage ratio (DR) is the fraction of the MAR that could be affected by the postulated accident and is a function of the accident initiator and the operation event being evaluated. The DR for each accident is discussed in the appropriate section.

Airborne Release Fraction. The airborne release fraction (ARF) is the coefficient used to estimate the amount of a radioactive material suspended in air and made available for airborne transport. The ARF for each accident is taken from the applicable bounding values presented in DOE-STD-3010-94 and is discussed in the appropriate section.

Respirable Fraction. The respirable fraction (RF) is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system. It is commonly assumed to include particles of 10 μm aerodynamic equivalent diameter or less. The RFs are taken from the applicable bounding values presented in DOE-STD-3010-94 and are discussed in the appropriate section.

Leak path factor. The leak path factor (LPF) is the fraction of radionuclides in aerosol transported through some enclosure.

The Radiological Safety Analysis Computer Program (RSAC)–6[33] is used to quantify the downwind radiological consequences of postulated accidents. The meteorological model in RSAC-6 calculates Gaussian plume diffusion using Pasquill-Gifford, Hilsmeier-Gifford, or Markee diffusion factors. The Markee and Hilsmeier-Gifford models are used to simulate releases over desert terrains. The Markee model is used to simulate releases whose duration is from 15 to 60 minutes, while the Hilsmeier-Gifford model is used to simulate releases whose duration is from a few minutes to 15 minutes.

Downwind concentrations from release of the nonradioactive contaminants are calculated using the equation

CONC = (ST/t) * WQ

where

CONC	=	downwind concentration
ST	=	quantity released to the environment
t	=	release time
χ/Q	=	Atmospheric diffusion factor. The (χ/Q) values are calculated by RSAC-6 for the appropriate diffusion conditions and distances

Risk Evaluation Guidelines. The radiological and hazardous chemical risk evaluation guidelines (EGs) used for this analysis are listed in Table 3-14.

Table 3-14. Risk evaluation guidelines.

Event/Accident Likelihood/Frequency	On-Site Worker Consequences	Off-Site Public Consequences
	Anticipated (1E-01 to 1E-02/yr)	
Radiological	5.0 rem (TEDE)”	0.5 rem (TEDE)”
Nonradioactive	EWG-1 or equivalent[b]	TLV-TWA[c]
	Unlikely (1E-02 to 1E-04/yr)	
Radiological	25 rem (TEDE)	5.0 rem (TEDE)
Nonradioactive	EWG-2 or equivalent	EWG-1 or equivalent
	Extremely Unlikely (1E-04 to 1E-06/yr)	
Radiological	100 rem (TEDE)[d]	25 rem (TEDE)
Nonradioactive	EWG-3 or equivalent[d]	EWG-2 or equivalent

Notes:

a. TEDE = Total Effective Dose Equivalent

b. ERPG = Emergency Response Planning Guide (American Industrial Hygiene Association) “Equivalent” means a concentration of a hazardous chemical causing potential health effects similar to ERPG-1 levels, but for which an ERPG-1 concentration has not been established (e.g., TLV ceiling level). Likewise, “equivalent” to ERPG-2 and ERPG-3 mean concentrations of hazardous chemicals causing potential health effects similar to ERPG-2/3 levels, but for which ERPG-2/3 concentrations have not been established.

c. TLV-TWA = Threshold Limit Value - Time-Weighted Average

d. These guidelines apply only to workers in a neighboring facility, not in-facility workers.

3.4.2 Design Basis Accidents

3.4.2.1 Uncovering a High Radiation Source

3.4.2.1.1 Scenario Development — This scenario assumes a high radiation source buried in the SDA is uncovered and exposes workers to direct gamma radiation emanating from the buried object. Table 3-10 identifies two mechanisms that could uncover such an object: accidentally exposing a source while installing the wells, or initiating subsidence by creating large voids in the subsurface with ISTD processing. This event is “unlikely.”

3.4.2.1.2 Source Term ***Analysis***—From EDF-3543, the bounding high-radiation source is 24,000 R/hr at 2 ft from centerline. There are 17 packages over 1,000 R/hr. Encountering a source above 1,000 R/hr is judged to be unlikely, Encountering a source less than 1,000 R/hr is therefore anticipated. For an event probability of “unlikely,” it is appropriate to use the “anticipated” source term for an overall probability of “unlikely.” Using the “unlikely” source term with the “unlikely” event produces an overall probability of “extremely unlikely.” Calculations for the unlikely scenario will be performed using the 1,000 R/hr source. Calculations for an extremely unlikely scenario will be performed using the upper limit source of 24,000 R/hr. The dose to a worker 10 ft from these two sources will be estimated qualitatively. Collocated worker (100 m) and offsite individual (6 km) are too far away to be significantly exposed.

If ISTD is performed in Pits 4, 5, 6, and 10, the highest source buried was less than 5 R/hr and this accident is no longer of concern.

3.4.2.1.3 Consequence Analysis — It is assumed that the high-radiation object is inadvertently uncovered so the radiation shines directly to the environment in the immediate area, and that work continues in that area for a period of time before the radiation field is discovered. The radiation field is attenuated with the square of the distance. For a source term of 1,000 R/hr at 2 ft, the exposure rate is 40 R/hr at 10 ft from the source. A facility worker 10 ft from the source would receive a dose of 5 Rem in seven minutes and 25 Rem in 37 minutes; thus, a facility worker is qualitatively estimated to receive a dose of "low." Doses to collocated workers at 100 m or offsite individuals at 3 km or 6 km would be negligible because of their distances from the source.

For the extremely unlikely case, the 24,000 R/hr source at 2 ft has an exposure rate at 10 ft of 960 R/hr. A worker 10 ft from the source would receive a dose of 100 Rem in less than 7 minutes. A facility worker is qualitatively estimated to receive a dose of "high," a collocated worker a dose of "low," and the offsite individual a dose of "negligible."

3.4.2.1.4 Comparison to ***Guidelines*—**As shown in Table 3-14, the worker dose of "high" for the extremely unlikely case exceeds the risk evaluation guideline; however, for extremely unlikely scenarios, safety-significant SSCs and/or TSR controls are not required for the facility worker.

3.4.2.1.5 Summary of Safety SSCs and ***TSR Controls*—**The primary means of protecting against direct radiation is maintaining the soil cover. This is currently done using the existing radiation protection program, and would continue to be done the same way for ISTD. The radiation protection program would require verifying the soil cover depth before placing the drilling equipment and would require procedures to inspect and monitor soil cover integrity during ISTD processing. Also, results from other accidents indicate a TSR Administrative Control is needed to establish and verify a minimum soil cover depth of 10 ft.

3.4.2.2 Underground Drum Explosion

3.4.2.2.1 Scenario Development — Flammable and potentially explosive materials are buried in the RWMC's SDA. The presence of these substances raises concern about the potential for fires and explosions. This section evaluates the consequences of an explosion. Since a fire in a single drum produces less energy to drive contaminants, the consequences of a fire are expected to be lower than an explosion.

Much of the waste from Rocky Flats contains mixtures of potassium and sodium nitrate salts. While potassium nitrate and sodium nitrate are not explosives, they can react rapidly when mixed with fuels to yield explosive effects. There are materials in the SDA that have the potential to react energetically with nitrates, especially under elevated temperature conditions. Concerns have been raised over the possibility of the explosive reactions of nitrates with oil, graphite, and cellulosic waste during heating. Molten nitrate salts may migrate into drums containing oils or combustibles and form explosive mixtures, which may then be initiated by heat to explode by detonation or deflagration.[7]

This scenario involves the deflagration of a container containing nitrate salts that interact with pyrolyzed combustible wastes or finely divided graphite waste, hydrogen resulting from radiolytic decomposition of organics and plastics, pyrophoric or reactive materials, or pressurized cylinders containing a flammable gas. The analysis includes the original contaminants in the SDA and an estimate of phosgene and hydrochloric acid generation, but does not include any other products resulting from the incomplete combustion of nonradioactive contaminants.

To assess the unmitigated consequences of a drum explosion, it is assumed that the original soil cover is in place, but that the enhanced 10 ft soil cover is not in place or has degraded so the cover is ineffective in completely containing the contents of the drum.

Such an accident involves the compounding of several unlikely conditions. Nitrates and combustibles would be intermingled with the soil, which inhibits forming an explosive mixture. Most of the drums are breached, so they cannot contain radiolytically generated hydrogen, which would dissipate into the soil. The soil cover would normally be in place, thus containing and limiting the effects of any reaction.

A single drum is assumed to explode and expel its hazardous contents upward through a breach in the soil cover. A single drum explosion is unlikely. The potential to detonate nearby drums is much less probable, thus becoming beyond extremely unlikely. It is assumed the contents reach the surface where they are transported downwind exposing collocated workers and offsite members of the public.

3.4.2.2.2 Source Term Analysis**—**The radioactive and nonradioactive hazardous material source terms are determined in EDF-3563.[34] The source term is developed for a single drum; however, results of this analysis can be applied to an explosion with a larger number of drum equivalents by multiplying the consequences reported for this scenario by the number of drum equivalents.

Anticipated, unlikely, and extremely unlikely hazardous material inventories have been developed. Because an explosion is unlikely, the anticipated inventory is appropriate for an overall event probability of unlikely. The overall event likelihood for an unlikely explosion combined with an unlikely inventory is extremely unlikely. The following analysis is for two cases: the unlikely scenario assuming an anticipated inventory and the extremely unlikely scenario assuming an unlikely inventory.

The damage ratio is based on the results of drum explosion tests while the airborne release factors and respirable factors are from DOE-HDBK-3010-94 for venting of pressurized volumes. The airborne release fraction could be reduced for the activation products in the inventory since the radionuclides would be expected to reside in solid metal objects; however, to be conservative, the airborne release fraction is not reduced for activation products.

The existing overburden provides some filtration of the radioactive material. An explosion would be expected to loosen but not completely expel the overburden above the explosion location. The assumption is based on the upper drums having approximately 3 ft of soil cover, while the average depth of drums would be on the order of 10 ft. From these observations, the soil is assumed to behave as a granular bed filter. Based on an analysis of granular bed filters,[35] 10 cm (4 in.) of overburden gives a leak path factor of 0.1. DOE STD-3009-94 allows the unmitigated analysis to "take credit for passive safety features that are assessed to survive accident conditions where that capability is necessary in order to define a physically meaningful scenario."

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. It is conservatively assumed that volatile chemicals are completely released to the atmosphere.

The asbestos, beryllium, cadmium, and lead in the SDA are considered to be in large pieces and not dispersible. The MAR for asbestos, beryllium, cadmium, and lead is set to 0.

The heat of the explosion might generate phosgene and hydrochloric acid. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[36] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the RR for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119.

The resulting radioactive source terms are listed in Table 3-15. The release rate of the ten nonradioactive hazardous materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km are listed in Table 3-16.

Table 3-15. Radioactive hazardous material source term and downwind doses for the underground drum explosion.

Radionuclide	MAR (Ci)	ST (Ci)	Collocated Worker Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)
Extremely Unlikely Event				
Am-241	1.1E+02	7.0E-03	3.3E+01	4.6E-02
Co-60	1.7E+02	1.1E-02	2.6E-02	3.6E-05
Fe-55	1.1E+02	7.5E-03	2.2E-04	2.9E-07
Cr-51	8.4E+01	5.6E-03	2.1E-05	2.9E-08
H-3	6.8E+01	4.5E-03	0.0E+00	0.0E+00
Ni-63	4.0E+01	2.7E-03	6.6E-05	9.0E-08
CO-58	3.1E+01	2.1E-03	2.5E-04	3.5E-07
Mn-54	2.5E+01	1.7E-03	1.3E-04	1.8E-07
Sr-90	2.3E+01	1.5E-03	2.1E-02	2.9E-05
Cs-137	1.8E+01	1.2E-03	4.0E-04	5.5E-07
Ce-144	9.1E+00	6.1E-04	2.4E-03	3.3E-06
	Total		33	0.046
	Guideline		100	25
Unlikely Event				
Am-241	7.4E-01	4.9E-05	2.3E–01	3.2E–04
Co-60	1.3E+01	8.4E-04	2.0E–03	2.7E–06
Fe-55	2.3E+01	1.5E-03	4.4E–05	6.1E–08
Cr-51	4.5E+00	3.0E-04	1.1E–06	1.6E–09
H-3	8.4E+00	5.6E-04	0.0E+00	0.0E+00
Ni-63	7.7E+00	5.1E-04	1.3E–05	1.7E–08
CO-58	2.1E+00	1.4E-04	1.7E–05	2.4E–08
Mn-54	1.8E+00	1.2E-04	9.1E–06	1.2E–08
Sr-90	3.7E+00	2.5E-04	3.4E–03	4.7E–06
Cs-137	3.6E+00	2.4E-04	8.1E–05	1.1E–07
Ce-144	8.4E-01	5.6E-05	2.2E–04	3.1E–07
	Total		0.24	0.00033
	Guideline		25	5

Note: Bold italics denotes evaluation guideline challenged or exceeded

Table 3-16. NRH material consequences for the underground drum explosion.

Material	MAR (g)	RR (mg/s)	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Extremely Unlikely Event				ERPG-3		ERPG-2
Phosgene		1.1E+03	***35***	4	0.048	0.8
Hydrochloric Acid		4.3E+03	140	224	0.19	30
Carbon tetrachloride	1.3E+05	4.8E+04	1500	4790	2.1	639
Hydrofluoric acid	3.0E+03	1.1E+03	36	41	0.049	16.4
Sodium nitrate	1.5E+06	2.8E+02	8.9	100	0.012	7.5
Uranium	1.5E+05	2.7E+01	0.87	10	0.0012	1
Tributyl phosphate	4.2E+02	1.6E+02	5.0	300	0.0069	10
Tetrachloroethylene	3.1E+04	1.1E+04	370	6890	0.51	1378
Potassium nitrate	7.7E+05	1.4E+02	4.6	500	0.0063	20
Trichloroethylene	3.9E+04	1.4E+04	460	26900	0.63	2690
Nitric acid	2.0E+02	7.4E+01	2.4	200	,0033	15
Unlikely Event				ERPG-2		ERPG-1
Phosgene		1.4E+01	0.45	0.8	0.00061	0.4
Hydrochloric Acid		3.6E+01	1.1	30	0.0016	4.5
Carbon tetrachloride	2.2E+03	8.1E+02	26	639	0.036	128
Hydrofluoric acid	2.5E+01	9.3E+00	0.30	16.4	0.00041	1.5
Sodium nitrate	1.2E+04	2.2E+00	0.071	7.5	9.8E-05	1
Uranium	1.2E+03	2.2E-01	0.0072	1	9.8E-06	0.6
Potassium nitrate	6.4E+03	1.2E+00	0.038	20	5.2E-05	3.5
Trichloroethylene	3.2E+02	1.2E+02	3.8	2690	0.0052	538
Tributyl phosphate	3.4E+00	1.3E+00	0.041	10	5.5E-05	6
Nitric acid	1.6E+00	5.9E-01	0.019	15	2.6E-05	3
Tetrachloroethylene	2.6E+02	9.6E+01	3.1	1378	0.0042	689

Note: Bold italics denotes evaluation guideline challenged or exceeded

3.4.2.2.3 Consequence Analysis — The dose and concentration consequences from the drum explosion are calculated using the Hilsmeier-Gifford dispersion model with 15-minute release duration.[34] Results are shown in Table 3-15 for radioactive materials and Table 3-16 for nonradioactive hazardous materials.

3.4.2.2.4 Comparison to the Evaluation ***Guideline***—The radiological dose consequences from the drum explosion scenario are compared to the unlikely and extremely unlikely evaluation guidelines in Table 3-15. No evaluation guidelines are exceeded.

Table 3-16 shows the concentrations of the ten nonradioactive materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km. The concentration of phosgene at

100 m exceeds the evaluation guidelines for the extremely unlikely event. Since phosgene does not exist in the waste and is hypothesized to be generated through the heat of the reaction, it is recommended that hrther analysis be performed to determine the likelihood of phosgene generation. From Figure 3-2, safety requirements should be identified to manage collocated worker risk. Emplacing 10 ft minimum soil cover will prevent the consequences of a drum explosion.

3.4.2.2.5 Summary of Safety SSCs and ***TSR*** Control — No safety class or safety-significant SSCs are required for this accident.

The soil cover will mitigate the consequences of a drum explosion. A TSR requirement should be established to maintain the soil cover.

3.4.2.3 Well Header Piping Failure

3.4.2.3.1 Scenario Development — In this scenario it is assumed that ISTD processing is ongoing. Melting and contaminant destruction are occurring in the vicinity of the heater wells and the off-gases are being drawn into the heaterhacuum wells. The affected area is one module of ISTD, which involves an area 122 x 97 ft and includes 96 heaterhacuum wells. Each well is drawing air and off-gases at 15 cfm per well. For 96 wells, the total off-gas flow rate is 1,500 cfm.

It is assumed a failure occurs in the off-gas header piping at a location near the off-gas treatment system where there is total off-gas flow. The total volume of air and gases in the well header piping is released to the environment. As soon as the piping is breached, the suction drawing gases through the piping and heaterhacuum wells will cease, because air is being drawn from upstream by the off-gas system-induced draft fans. Consequently, no additional off-gas is drawn into the heaterhacuum wells for release to the environment. This event is categorized as “unlikely.”

Another breach that could occur is an off-gas system failure of one or more components that would release its contents to the environment. The components most likely to contain significant quantities of hazardous material are the cyclone separator, the HEPA filters, and the oxidizer. Releases will only occur for large breaches. The system operates at negative pressure, so for small breaches, outside air will leak in and the off-gas system contents will remain in the system. As soon as a large breach occurs, the suction drawing gases through the piping and heaterhacuum wells will cease, because air is being drawn from downstream by the off-gas system-induced draft fans. Consequently, after a large breach, no additional contaminants are drawn into the off-gas system for release to the environment.

Most of the radionuclides, particularly the transuranics, will be in the cyclone separator and HEPA filters. The quantity will increase as processing continues, until the HEPA filters are replaced. As discussed in the well header piping failure analysis, the total quantity of transuranics available for release to the off-gas system during the entire process is the quantity in an area adjacent to the heaterhacuum wells. The off-gas system would not be expected to accumulate any more than this quantity; thus, for transuranics the well header piping failure accident should bound the consequences of an off-gas system breach.

DOE Handbook 3010 states that heat-induced damage to a HEPA filter is estimated to be very small. The filter medium is very fine diameter glass fiber that softens and melts when heated and thus tends to retain materials adhering to the fibers. The release rate for several types of HEPA filter in flowing air at elevated temperatures less than required to induce failure are very low.

There is no mechanism for retaining large quantities of NRH materials in the off-gas treatment system. Most of these should be in the cyclone separator, HEPA filters, or oxidizer where they are largely destroyed, and thus present only in very small quantities in downstream components. The quantities of NRH materials will be primarily as concentrations in the off-gas air. The total quantities will be proportional to the volume of the component. The component volumes are significantly smaller than the well header piping volume, so the well header piping failure will bound the NRH consequences for off-gas system breaches.

Based on the above considerations, consequences of off-gas system breaches are bound by the well header piping failure and will not be analyzed hrther.

3.4.2.3.2 Source Term Analysis**—**The radioactive and nonradioactive hazardous material source terms are determined in EDF-3854[37] with the results summarized in Tables 3-17 and 3-18. Best-estimate and limiting hazardous material inventories have been developed. Best-estimate corresponds to a likelihood category of anticipated and limiting corresponds to a likelihood category of unlikely. For the unlikely well header piping failure, the best-estimate inventory is appropriate for an overall event probability of unlikely. The overall event likelihood for an unlikely well header piping failure combined with a limiting inventory is extremely unlikely. Both conditions are evaluated in this analysis.

For transuranic contaminants, guidance in EDF-3543, Table 5 says to use either Pu-239-eq or Am-241. This is because drums generally contain either plutonium or americium, but not both. To maximize the receptor dose, the inventory is calculated for an area contaminated with Pu-239. The source term for fission and activation products is also determined from EDF-3543.

To determine the DR for nonvolatile radionuclides, including plutonium, and nonvolatile NRH materials, it is assumed the airflow through the waste transports the contaminants out of the waste and into the off-gas from a zone of 6-in. radius around each heaterhacuum well. The NRH nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. The filtration and retention effects of the soil and waste matrix hold materials beyond this zone in the soil and prevent their migration to the well. No credit is taken for the sand filter in the wells between the well casing and the heater pipe. The DR of 0.00641 is the ratio between the area around all the wells and the total treatment area.

A different approach is used to calculate the DR for volatile NRH materials. An assessment by MK Technology[38] states that greater than 50% of carbon tetrachloride will be destroyed by ISTD. Based on this analysis, it is estimated 50% of the volatile organics will be destroyed and the DR is 0.5.

Based on information showing that beryllium, mercury, and nitric acid were not buried in the TRU areas, they are not included in the accident calculations. The asbestos in the SDA is in large pieces and not dispersible. The DR for asbestos is set to 0.

Large quantities of HCl are created by destruction of chlorinated organics during ISTD processing. The quantity generated is estimated using a molar ratio HCl to $CCl_4 = 4.0$.

Phosgene can be produced through oxidation of carbon tetrachloride. The assessment by MK Technology states that CCl_4 will be decomposed before enough water is evaporated to make phosgene the primary product of decomposition and thus there is virtually no production of phosgene; however, for conservatism in this analysis, production of phosgene will be estimated by assuming 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[36] To implement the assumption, the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.0119. Using the total quantity of halogenated compounds is extremely conservative since all of the materials would not be expected to simultaneously exist in the same treatment area.

The melting temperature for the activated metals and NRH metals will determine their behavior during ISTD heating. Stainless steel will not melt, so the activated metals are expected to remain in the stainless steel and not be available for release. Cadmium and lead are expected to melt, but not volatilize; thus, cadmium and lead will be modeled as dispersible but nonvolatile materials. The other metals are modeled as non-dispersible.

The resulting radioactive source terms are listed in Table 3-17. The release rates of the 10 nonradioactive hazardous materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km are listed in Table 3-18.

Table 3-17. Radioactive hazardous material source term and downwind doses for the well header piping failure.

Radionuclide	MAR (Ci)	ST (Ci)	Collocated Worker Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)
Extremely Unlikely Event				
Pu-239 eq	1.23E+04	2.41E-06	1.11E-02	1.52E-05
Co-60	2.82E+05	0.00E+00	0.00E+00	0.00E+00
Fe-55	1.88E+05	0.00E+00	0.00E+00	0.00E+00
Cr-51	1.41E+05	0.00E+00	0.00E+00	0.00E+00
H-3	1.14E+05	4.47E-02	0.00E+00	0.00E+00
Ni-63	6.70E+04	0.00E+00	0.00E+00	0.00E+00
Co-58	5.17E+04	0.00E+00	0.00E+00	0.00E+00
Mn-54	4.23E+04	0.00E+00	0.00E+00	0.00E+00
Sr-90	3.88E+04	7.60E-06	1.06E-04	1.45E-07
Cs-137	2.94E+04	5.76E-06	1.97E-06	2.70E-09
Ce-144	1.53E+04	2.99E-06	1.20E-05	1.64E-08
	Total		1.12E-02	1.54E-05
	Guideline		100	25
Unlikely Event				
Pu-239 eq	1.23E+04	2.40E-06	1.11E-02	1.51E-05
Co-60	2.12E+04	0.00E+00	0.00E+00	0.00E+00
Fe-55	3.88E+04	0.00E+00	0.00E+00	0.00E+00
Cr-51	7.53E+03	0.00E+00	0.00E+00	0.00E+00
H-3	1.41E+04	5.53E-03	0.00E+00	0.00E+00
Ni-63	1.29E+04	0.00E+00	0.00E+00	0.00E+00
Co-58	3.53E+03	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.94E+03	0.00E+00	0.00E+00	0.00E+00
Sr-90	6.23E+03	1.22E-06	1.70E-05	2.33E-08
Cs-137	6.00E+03	1.17E-06	4.02E-07	5.51E-10
Ce-144	1.41E+03	2.76E-07	1.11E-06	1.51E-09
Total			1.11E-02	1.52E-05
Guideline			25	5

Note: Bold italics denotes evaluation guideline challenged or exceeded.

Table 3-18. NRH material source term and downwind concentrations for the well header piping failure.

Material	MAR (g)	ST (g)	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Extremely Unlikely Event				ERPG-3		ERPG-2
Hydrochloric acid	2.63E+08	5.36E+02	2.87E+01	224	3.94E-02	30
Phosgene	6.21E+06	1.27E+01	6.80E-01	4	9.32E-04	0.8
Carbon tetrachloride	5.53E+08	5.64E+02	3.03E+01	4,790	4.14E-02	639
Lead	1.05E+09	2.05E-01	1.10E-02	100	1.51E-05	0.25
Hydrofluoric acid	1.29E+07	1.32E+01	7.08E-01	41	9.70E-04	16.4
Tributyl phosphate	1.76E+06	1.80E+00	9.66E-02	300	1.32E-04	10
Sodium nitrate	6.23E+09	1.22E+00	6.55E-02	100	8.97E-05	7.5
Uranium	7.29E+08	1.43E-01	7.66E-03	10	1.05E-05	1
Tetrachloroethylene	1.29E+08	1.32E+02	7.08E+00	6,890	9.70E-03	1,378
Trichloroethylene	1.65E+08	1.68E+02	9.01E+00	26,900	1.23E-02	2,690
Unlikely Event				ERPG-2		ERPG-1
Hydrochloric acid	6.70E+06	1.37E+01	7.34E-01	30	1.01E-03	4.5
Phosgene	1.20E+05	2.45E-01	1.31E-02	0.8	1.80E-05	0.4
Carbon tetrachloride	1.41E+07	1.44E+01	7.73E-01	639	1.06E-03	128
Hydrofluoric acid	1.53E+05	1.56E-01	8.37E-03	16.4	1.15E-05	1.5
Lead	1.29E+07	2.53E-03	1.36E-04	0.25	1.86E-07	0.15
Sodium nitrate	7.64E+07	1.50E-02	8.03E-04	7.5	1.10E-06	1
Trichloroethylene	2.00E+06	2.04E+00	1.09E-01	2,690	1.50E-04	538
Tributyl phosphate	2.12E+04	2.16E-02	1.16E-03	10	1.59E-06	6
Uranium	8.94E+06	1.75E-03	9.39E-05	1	1.29E-07	0.6
Tetrachloroethylene	1.65E+06	1.68E+00	9.01E-02	1,378	1.23E-04	689

Note: Bold italics denotes evaluation rmideline challenged or exceeded

For plutonium, other radionuclides, and nonvolatile NRH materials, ARF = 5 E-4 from HDBK-3010. For volatiles ARF = 1.0. For all materials, RF = 1.0 per HDBK-3010.

The LPF is estimated as the percentage of total contaminant released by ISTD processing that is in the well header piping at the time of failure. It is assumed all the material in the well header piping is released. This is a conservative assumption that only applies to catastrophic failure. The piping and off-gas system are maintained at negative pressure, so small leaks in the system would cause air to leak in rather than the piping contents leaking out. For nonvolatile materials in the area around the well it is assumed all the material is processed in 24 hours and the LPF is 6.11 E-5. For volatile materials in the entire treatment area it is assumed the material is processed in 30 days and the LPF is 2.04 E-06.

3.4.2.3.3 Consequence Analysis — The dose and concentration consequences from the well header piping failure are calculated using the Hilsmeier-Gifford dispersion model with 15-minute release duration.[37] Results are shown in Table 3-17 for radioactive materials and in Table 3-18 for nonradioactive hazardous materials. Results are shown for both the unlikely scenario and the extremely unlikely scenario.

3.4.2.3.4 Comparison to the Evaluation ***Guideline***—The radiological dose consequences from the unlikely and extremely unlikely well header piping failure are compared to the appropriate evaluation guidelines in Table 3-17. Results show that no evaluation guidelines are exceeded.

Table 3-18 shows the concentrations of the 10 nonradioactive materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km. Results show no evaluation guidelines are exceeded.

3.4.2.3.5 Summary of Safety SSCs and TSR Control — No evaluation guidelines were exceeded, so no safety class or safety-significant SSCs are required.

3.4.2.4 Off-gas Treatment System Failure

3.4.2.4.1 Scenario Development — This scenario consists of discharging untreated air from the off-gas system to the environment. It is assumed that ISTD processing is ongoing. Melting and contaminant destruction are occurring in the vicinity of the heater wells and the off-gases are being drawn into the heaterhacuum wells. The affected area is one module of ISTD, which involves an area 122 x 97 ft and includes 96 heaterhacuum wells. Each well is drawing air and off-gases at 15 cfm per well. For 96 wells, the total off-gas flow rate is 1,500 cfm.

The off-gas system is described in Chapter 2. It consists of a filtration unit, an oxidizer, a dry scrubber, a carbon bed, and an induced fan. The filtration unit removes particulate material through a cyclone separator and HEPA filter banks. The flameless thermal oxidizer destroys halogenated organic compounds that have been thermally desorbed from the waste stream and did not become oxidized in the subsurface. Most of the contaminants in the waste stream will have been removed or destroyed after the gas passes through the oxidizer.

To assess the consequences of an unmitigated release from failure of the off-gas system, it is assumed that processing continues, but without any removal of contaminants by the off-gas system. This situation might occur through either equipment failure or operator error, resulting in bypassing or ineffective operation of the off-gas treatment system.

The design of the off-gas system limits the potential for an uncontrolled release. The off-gas components are arranged in series, with the induced draft fans at the downstream end of the lineup. The process relies on the fans to draw air through the waste material, into the heater vacuum wells, and into the off-gas system; however, the off-gas system components may be provided with bypass paths that could be incorrectly aligned, or some other unidentified event may occur.

The total quantity of material released depends on the duration of the accident and the source term. Two scenarios will be evaluated. The first scenario assumes a best-estimate source term and that the release is detected and terminated after 10 hours. Ten hours corresponds to a single shift. This event is considered unlikely. The second scenario assumes a limiting source term and the release is terminated after 10 hours. This event is considered extremely unlikely. The upper bound case would be a limiting source term and an accident that continues until all the underground contamination is released. Such an event is considered beyond extremely unlikely and is not evaluated.

***3.4.2.4.2 Source Term Analysis*—**The radioactive and nonradioactive hazardous material source terms are determined in EDF-3854, with the results summarized in Tables 3-19 and 3-20. Best-estimate and limiting hazardous material inventories have been developed. Best-estimate corresponds to a likelihood category of anticipated and limiting corresponds to a likelihood category of unlikely. For an unlikely off-gas system failure, the best-estimate inventory is appropriate for an overall event probability of unlikely. The overall event likelihood for an unlikely off-gas system failure combined with a limiting inventory is extremely unlikely. Both conditions are evaluated in this analysis.

For transuranic contaminants, guidance in EDF-3543, Table 5, says to use either Pu-239-eq or Am-241. This is because drums generally contain either plutonium or americium, but not both. To maximize the receptor dose, the inventory is calculated for an area contaminated with Pu-239. The source term for fission and activation products is also determined from EDF-3543.

To determine the DR for nonvolatile radionuclides, including plutonium, and nonvolatile NRH materials, it is assumed the airflow through the waste transports the contaminants out of the waste and into the off-gas from a zone of 6-in. radius around each heaterhacuum well. The NRH nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. The filtration and retention effects of the soil and waste matrix hold materials beyond this zone in the soil and prevent their migration to the well. No credit is taken for the sand filter in the wells between the well casing and the heater pipe. The DR of 0.00641 is the ratio between the area around all the wells and the total treatment area.

A different approach is used to calculate the DR for volatile NRH materials. The assessment by MK Technology[38] states that greater than 50% of carbon tetrachloride will be destroyed by ISTD. Based on this analysis, it is estimated 50% of the volatile organics will be destroyed and the DR is 0.5.

Based on information showing that beryllium, mercury, and nitric acid were not buried in the TRU areas, they are not be included in the accident calculations. The asbestos in the SDA is in large pieces and not dispersible, so its DR is 0.

Large quantities of HCl are created by destruction of chlorinated organics during ISTD processing. The quantity generated is estimated using a molar ratio HCl to CCl_4 = 4.0.

Phosgene can be produced through oxidation of carbon tetrachloride. The MK Technology assessment states that CCl_4 will be decomposed before enough water is evaporated to make phosgene the primary product of decomposition and thus there is virtually no production of phosgene; however, for conservatism in this analysis, production of phosgene will be estimated by assuming 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[36] To implement the assumption, the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane; 1,1,2-trichloro-1,2,2-trifluoroethane; carbon tetrachloride; chloroform; methylene chloride; tetrachloroethylene; and trichloroethylene) by 0.0119. Using the total quantity of halogenated compounds is extremely conservative since all of the materials would not be expected to simultaneously exist in the same treatment area.

The melting temperature for the activated metals and NRH metals will determine their behavior during ISTD heating. Stainless steel will not melt, so the activated metals are expected to remain in the stainless steel and not be available for release. Cadmium and lead are expected to melt, but not volatilize; thus, cadmium and lead will be modeled as dispersible but nonvolatile materials. The other metals are modeled as nondispersible.

For plutonium, other radionuclides, and nonvolatile NRH materials, ARF = 5 E-4 from HDBK-3010. For volatiles, ARF = 1.0. For all materials, RF = 1.0 per HDBK-3010.

The LPF is the ratio of the release time to the total processing time. The estimated time to release the nonvolatile materials in the 6-in radius area around the wells is 24 hours. For an accident duration of 10 hours, the LPF is 0.417. The estimated time to release all the volatile materials is 30 days, which is the estimated time to treat the carbon tetrachloride. For an accident duration of 10 hours, the LPF is 0.0139.

The resulting radioactive source terms are listed in Table 3-19. The source term for the 10 nonradioactive hazardous materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km are listed in Table 3-20.

Table 3-19. Radioactive hazardous material source term and downwind doses for the off-gas treatment svstem failure.

Radionuclide	MAR (Ci)	ST (Ci)	Collocated Worker Total Effective Dose Equivalent (rem)	Public (6 km) Total Effective Dose Equivalent (rem)
Extremely Unlikely Event				
Pu-239eq	1.23E+04	1.65E-02	9.64E+00	7.90E-02
Co-60	2.82E+05	0.00E+00	0.00E+00	0.00E+00
Fe-55	1.88E+05	0.00E+00	0.00E+00	0.00E+00
Cr-51	1.41E+05	0.00E+00	0.00E+00	0.00E+00
H-3	1.14E+05	3.05E+02	0.00E+00	0.00E+00
Ni-63	6.70E+04	0.00E+00	0.00E+00	0.00E+00
Co-58	5.17E+04	0.00E+00	0.00E+00	0.00E+00
Mn-54	4.23E+04	0.00E+00	0.00E+00	0.00E+00
Sr-90	3.88E+04	5.19E-02	9.13E-02	7.52E-04
Cs-137	2.94E+04	3.93E-02	1.71E-03	1.40E-05
Ce-144	1.53E+04	2.04E-02	1.04E-02	8.52E-05
	Total		9.74E+00	7.98E-02
	Guideline		100	25
Unlikely Event				
Pu-239eq	1.23E+04	1.64E-02	9.62E+00	7.88E-02
Co-60	2.12E+04	0.00E+00	0.00E+00	0.00E+00
Fe-55	3.88E+04	0.00E+00	0.00E+00	0.00E+00
Cr-51	7.53E+03	0.00E+00	0.00E+00	0.00E+00
H-3	1.41E+04	3.77E+01	0.00E+00	0.00E+00
Ni-63	1.29E+04	0.00E+00	0.00E+00	0.00E+00
Co-58	3.53E+03	0.00E+00	0.00E+00	0.00E+00
Mn-54	2.94E+03	0.00E+00	0.00E+00	0.00E+00
Sr-90	6.23E+03	8.33E-03	1.47E-02	1.21E-04
Cs-137	6.00E+03	8.02E-03	3.48E-04	2.86E-06
Ce-144	1.41E+03	1.89E-03	9.58E-04	7.87E-06
	Total		9.63E+00	7.89E-02
	Guideline		25	5

Note: Bold italics denotes evaluation guideline challenged or exceeded.

Table 3-20. NRH material source term and downwind concentrations for the off-gas svstem failure.

Material	MAR (g)	ST (g)	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Extremely Unlikely Event				ERPG-3		ERPG-2
Hydrochloric acid	2.63E+08	3.65E+06	***4.14E+02***	224	3.40E+00	30
Phosgene	6.21E+06	8.64E+04	***9.79E+00***	4	8.05E-02	0.8
Carbon tetrachloride	5.53E+08	3.84E+06	4.36E+02	4,790	3.58E+00	639
Lead	1.05E+09	1.40E+03	1.59E-01	100	1.30E-03	0.25
Hydrofluoric acid	1.29E+07	8.99E+04	1.02E+01	41	8.38E-02	16.4
Tributyl phosphate	1.76E+06	1.23E+04	1.39E+00	300	1.14E-02	10
Sodium nitrate	6.23E+09	8.33E+03	9.44E-01	100	7.76E-03	7.5
Uranium	7.29E+08	9.75E+02	1.10E-01	10	9.08E-04	1
Tetrachloroethylene	1.29E+08	8.99E+05	1.02E+02	6,890	8.38E-01	1,378
Trichloroethylene	1.65E+08	1.14E+06	1.30E+02	26,900	1.07E+00	2,690
Unlikely Event				ERPG-2		ERPG-1
Hydrochloric acid	6.70E+06	9.32E+04	1.06E+01	30	8.68E-02	4.5
Phosgene	1.20E+05	1.67E+03	1.89E-01	0.8	1.55E-03	0.4
Carbon tetrachloride	1.41E+07	9.81E+04	1.11E+01	639	9.14E-02	128
Hydrofluoric acid	1.53E+05	1.06E+03	1.20E-01	16.4	9.90E-04	1.5
Lead	1.29E+07	1.73E+01	1.96E-03	0.25	1.61E-05	0.15
Sodium nitrate	7.64E+07	1.02E+02	1.16E-02	7.5	9.52E-05	1
Trichloroethylene	2.00E+06	1.39E+04	1.58E+00	2,690	1.29E-02	538
Tributyl phosphate	2.12E+04	1.47E+02	1.67E-02	10	1.37E-04	6
Uranium	8.94E+06	1.19E+01	1.35E-03	1	1.11E-05	0.6
Tetrachloroethylene	1.65E+06	1.14E+04	1.30E+00	1,378	1.07E-02	689

Note: Bold italics denotes evaluation rmideline challenged or exceeded

3.4.2.4.3 Consequence Analysis — The dose and concentration consequences from the off-gas treatment system failure are calculated using the Markee dispersion model. The Markee model used is intended for time periods up to 2 hours. Using it for this accident is very conservative because it assumes the wind blows in a single direction at a very stable condition for the duration of the accident. This accident is postulated to occur for 10 hours, so the atmospheric diffusion will be much greater than modeled here. Results are shown in Table 3-19 for radioactive materials and in Table 3-20 for nonradioactive hazardous materials. Results are shown for both the unlikely scenario and the extremely unlikely scenario.

3.4.2.4.4 Comparison to the Evaluation ***Guideline***—The radiological dose consequences from the unlikely and extremely unlikely off-gas treatment system failure are compared to the appropriate evaluation guidelines in Table 3-19. Results show no evaluation guidelines are exceeded.

Table 3-20 shows the concentrations of the 10 nonradioactive materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km. Results show the evaluation guidelines for the collocated worker but not the offsite receptor are exceeded for the extremely unlikely event, and no evaluation guidelines are exceeded for the collocated worker for the unlikely event. The two NRH materials that exceed the guidelines are hydrochloric acid and phosgene. Neither of these is present in the waste, but they are predicted to be generated by ISTD processes. Further research on ISTD chemical processes is needed to confirm this result.

3.4.2.4.5 Summary of Safety SSCs and TSR Control — Because evaluation guidelines are exceeded, the off-gas treatment system, including the stack monitoring system, should be designated safety-significant. This may not be necessary if it can be shown the effects of hydrochloric acid and phosgene are overestimated in this analysis. Also, as indicated in Figure 3-2, it may be possible to designate these components as safety requirements rather than safety-significant.

3.4.2.5 Positive Pressure in the Subsurface Treatment Area

3.4.2.5.1 Scenario Development — This scenario consists of a failure such that the well system does not collect the treatment products and route them to the off-gas system. This could result from failure of the off-gas treatment system induced draft fans causing positive pressure in the off-gas system, or from an underground fire spreading beyond the treatment area where the heaterhacuum wells collect the treatment products. An underground fire in the ISTD treatment area would essentially be ISTD processing. The products would be collected by the off-gas system.

It would be very difficult for a significant fire to occur beyond the treatment area. Underground fires would rely on oxygen being drawn into the waste; however, the soil overburden and soil mixed with the waste will severely limit oxygen entering the system from the surface. Once a fire extended beyond the treatment area, there would be no heater wells to provide an external heat source and no vacuum to draw in air and circulate it through the waste to sustain combustion; thus there is little potential for a fire to extend far beyond the treatment area or burn on its own. Also, there is no significant driver mechanism to transport the combustion products or hazardous materials through the soil to the surface.

An induced draft fan failure is more likely to occur, and would impact a much greater area, so this analysis will be performed for positive pressure in the off-gas system resulting from an induced draft fan failure.

It is assumed that ISTD processing is ongoing. Desorption, melting, and contaminant destruction are occurring in the vicinity of the heater wells. The affected area is one module of ISTD, which involves an area 122 x 97 ft and includes 96 heaterhacuum wells. Each well is drawing air and off-gases at 15 cfm per well. For 96 wells, the total off-gas flow rate is 1,500 cfm. It is assumed that the off-gas system induced draft fan fails suddenly curtailing the inflow of gases to the off-gas system.

An induced draft fan failure would automatically initiate mitigative safety features, including starting the alternate fan and initiating backup power if needed; however, since this accident is evaluated for unmitigated consequences, it will be assumed automatic safety features are not initiated. Operators would eventually detect the fan failure and either restore fan function or curtail ISTD processing by turning off power to the heaters. It is assumed this failure is detected after one shift of 10 hours.

Without the fan drawing air through the system, ISTD treatment reactions would be reduced; however, the heaters would continue to heat the soil. The only significant mechanism to drive the underground contaminants or treatment products through the soil overburden to the surface would be heat from the ISTD heaters.

3.4.2.5.2 Source Term Analysis—The accident source terms are determined in EDF-3854, with the results summarized in Table 3-21. Best-estimate and limiting hazardous material inventories have been developed. Best-estimate corresponds to a likelihood category of anticipated and limiting corresponds to a likelihood category of unlikely. For an accident probability of anticipated, the best-estimate inventory is used. For an accident probability of unlikely, the limiting source term is used.

Based on information showing that beryllium, mercury, and nitric acid were not buried in the TRU areas, they are not included in the accident calculations.

Large quantities of HCl are created by destruction of chlorinated organics during ISTD processing. The quantity generated is estimated using a molar ratio HCl to $CCl_4 = 4.0$.

The melting temperature for the activated metals and NRH metals will determine their behavior during ISTD heating. Stainless steel will not melt, so the activated metals are expected to remain in the stainless steel and not be available for release. Cadmium and lead are expected to melt, but not volatilize; thus, cadmium and lead will be modeled as dispersible but nonvolatile materials. The other metals are modeled as nondispersible. The asbestos in the SDA is in large pieces and not dispersible.

Phosgene can be produced through oxidation of carbon tetrachloride. An assessment by MK Technology states that CCl_4 will be decomposed before enough water is evaporated to make phosgene the primary product of decomposition and thus there is virtually no production of phosgene; however, for conservatism in this analysis, production of phosgene will be estimated by assuming 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[36] To implement the assumption, the quantity of phosgene is calculated by multiplying the sum of the RR for the halogenated compounds (1,1,1-trichloroethane; 1,1,2-trichloro-1,2,2-trifluoroethane; carbon tetrachloride; chloroform; methylene chloride; tetrachloroethylene; and trichloroethylene) by 0.0119. Using the total quantity of halogenated compounds is extremely conservative since all of the materials would not be expected to simultaneously exist in the same treatment area.

In situ thermal desorption will be performed with the waste in place beneath the subsurface. It is assumed the heaters will continue to desorb and decompose the volatile materials. For this event, there is no breach created in the soil as would occur for a drum explosion. Also, there is no airflow into the well header piping and no breach in the well header piping or off-gas treatment system that would create a path to the environment. The DR for TRU, non-TRU radionuclides, and nonvolatile NRH is 1.0 for this accident. In situ thermal desorption processing will affect the entire area. These contaminants are not drawn into the heaterhacuum wells for this accident.

The DR is 0.5 for the volatile organic materials because it is estimated that the ISTD processes will destroy half of these materials.

The wastes being treated are mixed with soil and covered with an existing overburden. No credit is taken for the additional soil that will be added for a total depth of 10 ft; however, since there are no energetic drivers to disturb the soil or drive the contaminants to the surface, it is estimated that no Pu, other radionuclides, and nonvolatile nonradioactive contaminants will reach the surface and thus their ARF is 0.

For volatile materials, migration could result from gaseous convection driven by the heat from the heaters; therefore, it is assumed the volatile materials, including volatile organics and volatile decomposition products HCl and phosgene will migrate to the surface and be released with an ARF of 1.0. The RF is 1.0 for all materials per HDBK-3010.

To determine the LPF, it is estimated the time to complete treatment is 30 days, which is the time to treat the carbon tetrachloride. If the release is detected after one shift of 10 hours, the LPF is 0.0139.

Because the transuranics, fission product, and activation product radionuclides are contained by the soil, there is no radioactive material source term for this accident. The release rates of the 10 nonradioactive hazardous materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km are listed in Table 3-21.

Table 3-21. NRH material source term and downwind concentrations for positive pressure in the subsurface treatment area.

Material	MAR (g)	ST (g)	Collocated Worker Exposure Concentration (mg/m^3)	Worker Evaluation Guidelines (mg/m^3)	Public (6 km) Exposure Concentration (mg/m^3)	Public Evaluation Guidelines (mg/m^3)
Unlikely Event				ERPG-2		ERPG-1
Hydrochloric acid	2.63E+08	3.65E+06	***4.14E+02***	30	3.40E+00	4.5
Phosgene	6.21E+06	8.64E+04	***9.79E+00***	0.8	8.05E-02	0.4
Hydrofluoric acid	1.29E+07	8.99E+04	1.02E+01	16.4	8.38E-02	1.5
Carbon tetrachloride	5.53E+08	3.84E+06	4.36E+02	639	3.58E+00	128
Trichloroethylene	1.65E+08	1.14E+06	1.30E+02	2,690	1.07E+00	538
Tributyl phosphate	1.76E+06	1.23E+04	1.39E+00	10	1.14E-02	6
Formaldehyde	2.00E+05	1.39E+03	1.58E-01	12.5	1.29E-03	1.25
Ammonia	2.47E+06	1.72E+04	1.95E+00	105	1.60E-02	17.5
Sulfuric acid	2.00E+05	1.39E+03	1.58E-01	10	1.29E-03	2
1,1,1-trichloroethane	1.65E+08	1.14E+06	1.30E+02	3,850	1.07E+00	1925
Anticipated Event				ERPG-1		TLV-TWA
Hydrochloric acid	6.70E+06	9.32E+04	***1.06E+01***	4.5	8.68E-02	0.75
Phosgene	1.20E+05	1.67E+03	1.89E-01	0.4	1.55E-03	0.4
Carbon tetrachloride	1.41E+07	9.81E+04	1.11E+01	128	9.14E-02	60
Hydrofluoric acid	1.53E+05	1.06E+03	1.20E-01	1.5	9.90E-04	1.5
Tetrachloroethylene	1.65E+06	1.14E+04	1.30E+00	689	1.07E-02	150
Formaldehyde	2.47E+03	1.72E+01	1.95E-03	1.25	1.60E-05	0.35
Tributyl phosphate	2.12E+04	1.47E+02	1.67E-02	6	1.37E-04	5
Trichloroethylene	2.00E+06	1.39E+04	1.58E+00	538	1.29E-02	500
Methylene chloride	2.47E+05	1.72E+03	1.95E-01	696	1.60E-03	75
Sulfuric acid	2.47E+03	1.72E+01	1.95E-03	2	1.60E-05	1
Ammonia	2.94E+04	2.04E+02	2.32E-02	17.5	1.90E-04	15

Note: Bold italics denotes evaluation guideline challenged or exceeded

3.4.2.5.3 Consequence Analysis — Because there are no radioactive releases, there are no radiological dose consequences for this accident. The NRH concentrations from the positive pressure accident are calculated using the Markee dispersion model. The Markee model used is intended for time periods up to 2 hours, whereas this accident is postulated to occur for 10 hours. Using it for this accident is very conservative because it assumes the wind blows in a single direction at a very stable condition for the duration of the accident; thus, the atmospheric diffusion will be much greater than modeled here. Results are shown in Table 3-21.

3.4.2.5.4 Comparison to the Evaluation ***Guideline***—Because there are no radiological dose consequences, no radiological evaluation guidelines are exceeded.

Table 3-21 compares the concentrations of the volatile nonradioactive materials with the evaluation guidelines for the collocated worker and receptor at 6 km. Results show that the evaluation guidelines for the collocated worker, but not the offsite receptor, are exceeded for both scenarios. Two NRH materials that exceed the guidelines are hydrochloric acid and phosgene. Neither of these are present in the waste, but they are predicted to be generated by ISTD processes. Further research on ISTD chemical processes is needed to confirm this result.

3.4.2.5.5 Summary of Safety SSCs and ***TSR*** Control — Because the evaluation guidelines are exceeded for all events, safety-significant SSCs and TSRs are needed to protect against the consequences of this accident. The off-gas treatment system, including the induced draft fans, should be designated safety-significant. Also, the soil pressure monitors will detect positive pressure and should be designated safety-significant. The soil cover will mitigate the consequences of a positive pressure accident. A TSR requirement should be established to maintain the soil cover.

3.5 References

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4. SAFETY STRUCTURES, SYSTEMS, AND COMPONENTS

4.1 Introduction

This chapter provides details on facility structures, systems, and components (SSCs) that are necessary for the facility to satisfy evaluation guidelines, provide defense-in-depth, or contribute to worker safety. The attributes required to support the safety hnctions identified in the hazard and accident analyses and support subsequent derivation of technical safety requirements is described.

4.2 Requirements

The following codes, standards, regulations, and DOE Orders are specific to this section and pertinent to the safety assessment:

- 10 CFR 830, Subpart A, "Quality Assurance Requirements"'
- 10 CFR 830, Subpart B, "Safety Basis Requirements"[2]
- DOE Order 420.1A, "Facility Safety"[3]
- DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis"[4]
- DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses"[5]
- DOE-ID, *Architectural Engineering Standards*.[6]

4.3 Safety-Class Structures, Systems, and Components

DOE-ID Order 420.D defines safety-class as the SSCs for which responsibility must be taken, either preventive or mitigative, to meet the risk evaluation guidelines for the off-Site public.

The result of the analyses of bounding and representative unmitigated accidents in Section 3 is that doses to the off-Site public are within the risk evaluation guidelines; therefore, there is no safety-class equipment for in situ thermal desorption operations.

4.4 Safety-Significant Structures, Systems, and Components

Safety-significant SSCs are those that prevent or mitigate postulated abnormal scenarios that might result in a worker fatality, or are in the anticipated or unlikely frequency range that could result in the following consequences to immediate area or collocated on-site workers:

- Total effective dose equivalent more than 25 Rem
- Exposure to life-threatening concentrations of hazardous chemicals (>ERPG-3 levels)
- Exposure to explosion overpressures causing serious injury (>10 psi).

The safety significant SSCs for in situ thermal desorption are the off-gas treatment system, including the induced draft fans and the stack monitoring system; the standby diesel generator; and the soil pressure monitors.

4.4.1 Off-gas Treatment System

4.4.1.1 Safety Function. The off-gas treatment system performs several safety hnctions, including the following:

- Remove radioactive and nonradioactive contaminants from the off-gas stream before the air is released to the environment.

- Contain the radioactive and nonradioactive hazardous contaminants in the off-gas stream and trapped in the off-gas system equipment.

- Maintain negative pressure in the heaterhacuum wells, the well header piping, and the off-gas treatment system to assure contaminants are drawn into the off-gas treatment system rather than being released directly to the environment.

4.4.1.2 System Description. The off-gas treatment system will be mounted on five semi trailers as shown in Chapter 2. Trailer-mounted components include a cyclone separator, HEPA filters, a regenerative oxidizer, (which contains a propane burner and two ceramic oxidizing beds), a compact cross flow heat exchanger, three dry gas scrubbers, three carbon adsorbers, two induced draft fans, an exhaust stack, the effluent monitoring system, and the standby diesel generator.

One trailer will have the cyclone separator and HEPA filters, a second trailer will contain the oxidizer and a third trailer will house the dry scrubber, carbon beds, induced draft fan, and stack. The propane system, housed on a fourth trailer, will include the propane tank and piping/valves going to the thermal oxidizer propane burner. The fifth trailer will hold the standby diesel generator.

The induced draft fans maintain a negative pressure in the well header piping network and pull the gas stream through the treatment processes on the trailers.

Once the soil has been heated, it is essential that a vacuum be maintained throughout the rest of the remediation. In the event of a power outage, the standby generator will be used to maintain power to the off-gas system to ensure that gases are processed through the oxidizer and carbon beds. The heater and vacuum/heater wells will be shut down upon loss of utility power to prevent the generation of additional gases.

The overall process system will be controlled by a supervisory programmable logic controller (PLC) located within the control room of the trailer. A visual monitor will display operating status of system components to the operator through a personal computer.

In addition to system control, the operator's computer will provide data logging. Throughout the off-gas treatment process, vapor stream temperatures and flow rates will be monitored and recorded.

Vacuum pressure will be measured continuously using Magnahelic gauges, and the temperatures within the oxidizer will be monitored continuously using thermocouples. In the event of thermocouple malfunction, the system will identify the defective component, which is then replaced or repaired. Heat exchanger temperatures will be monitored at the hot and cold sides of the stream and be tied to the process control system. The temperature and circulation rate of the water in the exchanger will be adjusted to control the temperature of the vapor stream feeding the dry scrubbers and carbon beds to ensure efficiency and safety. The exhaust stream from the off-gas trailer exhaust flow will be monitored continuously for the release of hydrocarbons and radionuclides. The monitoring system will consist of an isokinetic sampling system and a Constant Air Monitor (CAM).

4.4.1.3 Functional Requirements. Detailed hnctional requirements will be developed as part of designing the well header piping system. To perform its safety hnctions, the system must be designed to do as follows:

- Process the total volume of off-gas from the well field, which is expected to be approximately 1,500 scfm
- Provide a negative pressure of approximately 20 in. of water at the heaterhacuum well head
- Process the off-gas at temperatures up to 800°F coming from the well header piping
- Be a hlly enclosed system to maintain a negative pressure and contain hazardous materials
- Destroy organic compounds with 99.9999% efficiency
- Remove all transuranic radionuclides from the waste stream
- Destroy halogenated acids such as HCl generated through the hydrocarbon decomposition process
- Provide power from an emergency diesel generator to the off-gas system and associated instrumentation upon loss of normal power
- Sustain the mechanical loads imparted by the system during normal operation and potential accidents, including thermal expansion, subsidence, and seismic loading
- Be constructed of materials that prevent corrosion by the corrosive materials at temperatures that may be experienced in the system
- Continuously monitor the exhaust stream for the release of hydrocarbons and radionuclides.

4.4.7.4 System Evaluation. Detailed design for the off-gas treatment system has not been completed at this time. The system will be designed to meet the performance and safety criteria. Meeting the hnctional requirements and implementing the appropriate procurement, fabrication, and installation quality requirements will ensure the system satisfies its performance requirements.

4.4.7.5 Technical Safety Requirements Controls. Technical Safety Requirement Administrative Controls for quality assurance will be established for the procurement, fabrication, installation, and testing of the off-gas treatment system as appropriate for a safety-significant SSC.

Limiting conditions of operation and surveillance requirement controls will be established to verify the operability of the off-gas treatment system.

4.4.2 Soil Pressure Monitors

4.4.2.1 Safety Function. The safety function of the soil pressure monitors is to detect positive pressure in the subsurface treatment area, allowing operators to take action to prevent hazardous materials being released.

4.4.2.2 System Description. A number of soil pressure probes will be placed around the perimeter and at discrete points within the well field. The probes will monitor soil pressure and allow collection of gas/vapor samples.

4.4.2.3 Functional Requirements. Detailed hnctional requirements will be developed as part of designing the soil pressure monitors. To perform its safety hnctions, the system must be designed to do as follows:

- Monitor soil pressure at discrete points in the well field
- Sample gases and vapors at discrete points in the well field.

4.4.2.4 System Evaluation. Detailed design for the soil pressure monitors has not been completed at this time. The system will be designed to meet the performance and safety criteria. Meeting the hnctional requirements and implementing the appropriate procurement, fabrication, and installation quality requirements will ensure the system satisfies its performance requirements.

4.4.2.5 Technical Safety Requirements Controls. Technical safety requirements Administrative Controls for quality assurance will be established for the procurement, fabrication, installation, and testing of the soil pressure monitors as appropriate for a safety-significant SSC.

Limiting conditions of operation and surveillance requirement controls will be established to verify the operability of the soil pressure monitors.

5. Derivation of Technical Safety Requirements

5.1 Introduction

This chapter defines technical safety requirement (TSR) level controls to ensure safe operation during in situ thermal desorption (ISTD). New TSRs will be required to verify operability and condition of the off-gas treatment system and the soil pressure monitors.

Technical Safety Requirements will be derived from the following codes, standards, and Department of Energy (DOE) orders:

- DOE-ID Order 420.D, Requirements and Guidance for Safety Analysis
- DOE Order 420.1A, Facility Safety
- DOE Order 5480.22, Technical Safety Requirements
- DOE-STD-3009, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports
- 10 CFR 830, Nuclear Safety Management
- DOE G 423.1-1 Implementation Guide for Use in Developing Technical Safety Requirements.

5.2 Technical Safety Requirement Coverage

This chapter of the preliminary documented safety analysis addresses only TSRs proposed for ISTD. When the final Safety Analysis Report is written, the TSRs will be completed and the Radioactive Waste Management Complex TSR document revised to incorporate the ISTD TSRs.

5.3 Derivation of Facility Modes

Operational modes will be derived as part of the final Safety Analysis Report.

5.4 TSR Derivation

5.4.1 Safety Limits, Limiting Control Settings, and LCOs

The ISTD system will be designed to incorporate operational safety. Limiting conditions of operation controls will be established to address the operability of the off-gas treatment system, including effluent monitoring and standby diesel generator, and soil pressure monitors.

5.4.2 SRs

Surveillance requirement controls will be established to verify the operability and condition of the off-gas treatment system, including effluent monitoring and standby diesel generator, and soil pressure monitors.

5.4.3 Administrative Controls

A TSR Administrative Control is needed to emplace and maintain the soil cover. The 5,000-gal propane tank for the off-gas treatment system will be designed and operated to NFPA-58. Technical Safety Requirements Administrative Controls for quality assurance will be established for the procurement, fabrication, installation, and testing of the off-gas treatment system (including effluent monitoring and standby diesel generator) and soil pressure monitors as appropriate for a safety-significant SSC.

5.5 Design Features

It is expected that all passive design features will have TSRs. This will be reviewed as the design is developed.

5.6 Interface with Technical Safety Requirements from Other Facilities

In situ thermal desorption will be performed at the RWMC's SDA; thus, ISTD operations will be under TSR-4, *Technical Safety Requirements for the Radioactive Waste Management Complex*. In situ thermal desorption would also be encompassed by site-wide INEEL TSR controls contained in TSR-100, *INEEL Standardized Technical Safety Requirements Document.*

5.7 References

None

6. CRITICALITY PREVENTION

6.1 Introduction

The hazard analysis in Section 3.3 of this FS-PDSA identifies nuclear criticality as a potential hazard during in situ thermal desorption (ISTD) operations. The treatment area contains many times the minimum critical mass of fissile material; however, the fissile materials in the buried waste occur as contaminates at low concentrations. A criticality safety evaluation has been completed for ISTD.' This chapter summarizes the criticality safety analysis and the reasons controls are not needed to prevent nuclear criticality from ISTD.

6.2 Requirements

The governing U.S. Department of Energy (DOE) requirements for nuclear criticality safety include requirements from DOE Order 420.1A, Facility Safety[2] and guidelines for preparing nonreactor nuclear facility criticality safety evaluations in DOE-STD-3007-93.[3]

6.3 Criticality Concerns

6.3.1 Criticality Safety Principles and Criteria

The fundamental requirement for criticality safety is that before a new operation with fissionable materials begins, or before an existing operation changes, the entire process will be evaluated under both normal and credible abnormal conditions and compared against the following established basic acceptance criteria:[4]

- **The double contingency principle:** The double contingency principle recommends that sufficient safety factors be incorporated into design or procedures so that at least two unlikely and independent changes in process conditions (parameters) occur before a criticality accident is possible. No single failure results in the potential for a criticality accident. When controls cannot be applied to multiple independent parameters, a system of multiple controls on a single parameter is allowed. The number of controls required for a single parameter is based on the reliability of each control and any features that minimize the effect of their failure (e.g., shielding). The double contingency principle is applied to all credible scenarios for criticality accidents to determine the required design features and administrative controls.

- **Passive engineered control:** Passive control requires no intervention by an operator and is the preferred control method. It is usually implemented by specifying a system geometry that prevents criticality. If passive engineered control is not feasible, active engineered controls (those requiring human intervention) are preferred next. Administrative controls are limits imposed to process parameters and are least preferred.

- **A maximum calculated k-eff of 0.95 after a single failure:** When reliance is based on analytic methods rather than accepted experimental or handbook data, the calculated k-eff must include the uncertainties of the calculational method and the effects of credible accidents, corrosion, and tolerances.

6.3.2 Criticality Safety Evaluations

The methodology and results of the criticality safety evaluation are discussed in the following paragraphs. Only Pu-239 is included, since it is by far the most reactive and abundant fissile material. The waste in the SDA is critically safe in its current configuration.[5]

6.3.2.1 Analysis Overview. The analysis includes evaluation of various configurations to determine any criticality concerns with using the ISTD process. The criticality safety evaluation addressed three phases:

- Initial application of the process
- Final configuration resulting from processing
- Ancillary issues relating to ISTD and criticality safety.

During the initial application, the fissile-bearing waste is subjected to various processes that could increase the possibility of a criticality. These processes include the following:

- Creating pathways for water entry
- Concentrating the fissile material by reducing the waste volume
- Transporting the fissile material with air and reaction products drawn through the waste material, heater/vacuum wells, and off-gas system
- Altering or creating potential moderating materials by melting, volatilization, and chemical reaction.

The evaluation addressed several potential criticality scenarios that are representative of these processes. Some of the scenarios were evaluated qualitatively, and others through computational modeling.

6.3.2.2 Fissile Material Chemical Form. The chemical form of the fissile materials affects their response to ISTD processing. There are three possible forms for plutonium at the start of processing: oxide, salt, and metal. Plutonium and uranium are thermodynamically stable in the oxide form. The fissile oxides are nonvolatile, with low vapor pressures and melting temperatures higher than ISTD temperatures.

Some plutonium might have originally been deposited in metallic form, specifically that associated with metal crucibles (metal waste matrix) and nonmetal molds and crucibles (graphite, glass/slag waste matrices). Any plutonium disposed in metallic form is expected to have at least an outer oxide film. Small metal pieces are expected to be completely oxidized.[6]

The analysis of plutonium metal oxidation before any thermal treatment demonstrates that at room temperature and 100% relative humidity, spherical particles less than 0.5 in. in diameter will completely oxidize in 27 years.[7] All waste below ground in the SDA waste pits has been buried for at least that long. It is reasonable to expect that the waste has been subject to high relative humidity at times, especially with 3 flood events during these 27 years. Uranium metal is expected to oxidize in a similar fashion. If the oxidation of plutonium is not complete because of organic coatings, it will be oxidized during ISTD heating, as these coatings are removed.

The heating proceeds slowly and the vacuum brings in small amounts of air so oxides have adequate time to form. Plutonium and uranium salts, particularly nitrates, might dissociate as temperature rises. The resulting positively charged fissile ions would oxidize. The temperature is too low to vaporize halide, carbonate, and sulfate salts.

The plutonium oxidation rate increases greatly as the temperature rises. Even if a metal piece as large as a plutonium button (2 kg) were present in the waste, the duration of the ISTD heating and cooling period is likely to be sufficient to ensure oxidation and possible incorporation onto soil or sludge matrix.

ISTD will not reduce the plutonium back to a metal since the oxide is very stable. The oxidation potentials for plutonium are sufficiently high that ISTD would not result in reduction of the oxides to the metal. The melting temperature of PuO_2 is 2,400°C, while the maximum temperatures expected in ISTD are about 800°C. PuO_2 can be reduced to a metal in the presence of tantalum or calcium to form a slag. However, the process is not very effective and there is no tantalum in the soil and calcium is present only as the oxide. There is actually a good amount of calcium oxide in the soil, but the fact that it is already oxidized means it does not seek the oxygen from PuO_2; therefore, the driving force for reduction of PuO_2 to plutonium metal via calcium is not in the waste.

6.3.2.3 Concentration of Fissile Material. One scenario is formation of a critical configuration through concentration of fissile material during ISTD processing. The minimum critical mass for Pu-239 in a moist-oxide form (1.5 **wt%** H_2O), rather than a solution, is 10.2 kg for a system at full density and h1ly reflected by water.'

The total quantity of fissile isotopes buried at the SDA has been estimated to be about 350 kg of actinides. Thus, if all the actinides were plutonium and all the were concentrated in the entire SDA, it would be about 35 times the minimum critical mass for a moist oxide; however, the fissile material is mostly dispersed at low concentration throughout the waste. Fissile material exists primarily as contamination on the waste material. A few items—such as filters and graphite material—may contain larger amounts of fissile material; however, these items make up a small percentage of the total waste both by mass and volume.[9]

The plutonium oxide is generally an insoluble form, so it will not dissolve and concentrate. No credible mechanism that would concentrate a large amount of fissile material has been identified.

Based on the low overall concentrations of fissile material within the waste, the likelihood that oxidation of any metal has occurred, and the inherent difficulty of ISTD reducing oxide to a metal form, the formation of a critical system due to the concentration of plutonium metal within the waste matrices of the SDA is not credible.

6.3.2.4 Moderation of Plutonium by Mixing with Polyethylene. Waste matrices can be grouped as containing the following major components: polyethylene, graphite, glass (or slag), cellulose, concrete, metals, salts, or brick. Polyethylene, cellulose, and graphite are present in some waste matrices, and represent effective carbon-based neutron moderators and reflectors.''

This discussion considers the combining of plutonium and polyethylene. Polyethylene is superior to water as a neutron reflector/moderator. Polyethylene is a thermoplastic, which melts at 85–110°C; the exact temperature varies with physical properties such as the density, cross-linking frequency, and the degree of crystallinity. Cellulose decomposes at 260–270°C, rather than melt.'' Graphite, also an effective moderator, does not melt nor decompose, but reacts with oxygen at 110°C. Virtually all moderators except graphite, including water and most organic materials, leave the heated area undergoing volatilization and destruction (combustion, if oxidizer is present; or pyrolysis, if oxidizer is absent).

Polyethylene plastic begins melting with the water vaporization and is completely melted after the water is gone. The moderating water will not be present by the time polyethylene has had sufficient time to melt and pool.

Several things must happen to cause a criticality during heating of buried waste:

- Polyethylene must first melt during the initial phase of ISTD before temperatures reach levels sufficient to destroy it.
- The melted polyethylene must then selectively entrain or combine in a homogeneous fashion with the fissile isotopes.
- The melted plastic and fissile material must then flow and concentrate in a single area.
- This arrangement must be of sufficient concentration and proper shape to moderate neutrons sufficiently to cause a criticality.

Polyethylene is not likely to concentrate fissile material to any extent because it will continue to flow until it pyrolyzes or volatizes. The solubility of plutonium in molten polyethylene plastics is likely to be very low, based on the insolubility of most metals in aliphatic nonpolar organic materials. Polyethylene, even in larger quantities, does not have the ability to entrain or dissolve appreciable amounts of fissile material, nor does it have any concentrating capacity.

Polyethylene is very viscous during a slow melt. The speed of the heating would determine whether the polyethylene would melt and flow before it is vaporized or pyrolyzed. Polyethylene fluidity in the temperature range between melting and decomposition is low. Although there could be localized movement of molten polyethylene, there will be little if any movement within the waste, which is required for postulating sufficient concentration of fissile material. Moderation from this material is thus not realistically credible for multiple containers on a pit-wide basis.

Calculations performed for in situ vitrification demonstrate the fissile masses necessary to postulate a critical system composed of plutonium and polyethylene, in conjunction with the optimal geometry, reflection conditions, fissile concentration, and lack of diluent/absorber material. [12] The amount of fissile mass necessary in a localized area and the concurrent conditions necessary lead to the conclusion that the formation of a critical system due to the initial application of the ISTD process is not credible.

6.3.2.5 Flooding or Water Reentry. Another concern is the chance of a criticality occurring if water percolates back into the waste matrix, since there will be voids in it after the ISTD process. Movement of soil into voids left by water and organic materials will reduce the void space.

Although the SDA does not lie on a flood plain, local runoff from rapid spring thaws has caused flooding that covered part of the SDA. A 4.6 m (15 ft) dike has since been built around the SDA to prevent future flooding.

Flooding while the wells are being placed in the ground is not a concern. Analysis of the waste matrix in its current form shows no criticality concern because of flooding. Drilling ISTD wells will not change the waste matrix enough to invalidate that conclusion. Current requirements for coring and probing in the SDA require that probe casings and core holes have a maximum 6-in internal diameter and a minimum 5-ft edge-to-edge distance between the probe holes. The ISTD wells satisfy both these requirements, since the wells have a maximum 4-in nominal inside diameter and a 6.63-ft nominal edge-to-edge spacing.

The reintroduction of water can only cause concern if it dissolves plutonium that then collects in one place. Fissile isotope type, concentration, geometry, moderation and reflection are important in judging the importance of water concentration after ISTD treatment. The chemical form of the fissionable material after treatment determines solubility and ability to concentrate it. The water held in the waste following treatment must have intimate contact with the fissile material (as in a solution) to be effective as a moderator; however, plutonium oxide does not dissolve in water.

To assess the impact of water intrusion into the plutonium-contaminated waste, computer simulations of criticality scenarios were performed in the criticality safety evaluation. These scenarios consisted of various geometrical configurations of fissile material surrounded by water-saturated soil. The results are summarized in Table 6-1.

Table 6-1. Results of water intrusion criticality scenarios.

Critical Configuration	Variables	Conclusion	Minimum critical PuO_2
Water-moderated PuO_2 sphere	Radius and PuO_2 concentration	As concentration decreased critical mass decreased	8.0 kg
Water-saturated PuO_2 and soil sphere	Radius and PuO_2 concentration	As concentration decreased critical mass decreased	22.0 kg
Slab of water-moderated PuO_2 having the diameter of a 55-gallon drum (22.5 in.)	Slab thickness and the PuO_2 concentration	As concentration decreased the critical mass decreased	23.0 kg
Slab of water-saturated PuO_2 and soil having the diameter of a 55-gallon drum (22.5 in.)	Slab thickness and the PuO_2 concentration	As concentration decreased the critical mass decreased	41.0 kg
Infinite slab of water-moderated PuO_2	Slab thickness and the PuO_2 concentration	As concentration decreased the critical thickness increased	2.8-cm-thick slab
Infinite slab of water-saturated PuO_2 and soil	Slab thickness and the plutonium PuO_2	As concentration decreased the critical thickness increased	4.4-cm-thick slab

These models show the amount of fissile material necessary to form a critical system. The conclusion from these assessments was that none of these scenarios lent themselves to the credible formation of a critical system.

6.3.2.6 ***Collection of Fissile Materials in the Off-gas System.*** The last aspect of the proposed ISTD process addressed from a criticality safety standpoint was the possibility to formulate a critical configuration in the off-gas collection system. Accumulation of sufficient fissile material in the off-gas system to cause a criticality event is not credible. Most of the fissile material will remain in the soil. The sand between the heater and the slotted vacuudheater well casing will prevent particulate from entering the vacuudheater well and serve as a roughing filter for the off-gas. The amount of plutonium that can migrate from the treated soil, through the sand filters, and through the well header piping will not be significant. An extremely low amount of fissile material is expected to enter the off-gas system. The quantity of fissile material that does enter the system will be insufficient to cause a criticality.

6.3.2.7 Conclusions. In order to create a critical configuration with reasonable quantities of fissile material, these factors must be met:

- An unsafe mass of fissile material must be present.
- This fissile mass must be concentrated and in a favorable or optimal geometrical configuration.
- The system needs neutron moderation, full reflection, and must be free from diluent- or neutron-absorbing materials.

The fissile material in the SDA is dispersed at relatively low concentrations. If an area of fissile material existed with a higher concentration, the various factors above would need to be near optimal to achieve an unsafe condition. Approximately 10.2 kg of moist (1.5 **wt%** water) PuO_2 is required to create an unsafe condition. This system consists of uniform concentration of fissile material in a small volume, which is free of diluent materials and h1ly reflected by an infinite perfect reflector. These ideal conditions do not exist in the SDA, nor will the application of the ISTD process create them.

For more reasonable fissile masses, the optimal conditions are even more necessary to create an unsafe condition. These optimal conditions do not exist in the SDA. The conclusion of the evaluation is that there is no credible scenario associated with the ISTD process to formulate a critical system.

6.4 Criticality Controls

6.4.1 Engineering Controls

Based on the results of the analysis for ISTD operations, an inadvertent criticality is deemed incredible and no engineering controls are required.

6.4.2 Administrative Controls

Based on the results of the analysis for ISTD operations, an inadvertent criticality is deemed incredible and no new administrative controls are required.

The RWMC already has restrictions on placing wells in the SDA that will apply to ISTD well placement:

- The maximum internal diameter of probe casings and core holes shall be 6-in.
- There shall be a minimum distance of 5 ft inside edge-to-edge distance between unfilled nonferrous probe casings and core holes.
- Unfilled nonferrous casings or core holes may be allowed closer than 5 ft inside, edge-to-edge, if the existing casing/hole is filled with a material to effectively displace waste OR a demonstrated assaying technique is used to verify that an unsafe mass does not exist between casing/holes. The use of fill material and methods/controls for assaying requires review and approval from the Criticality Safety Group.

Current plans satisfy these requirements because the wells are less than 6-in diameter and the casings are stainless steel, which is a ferrous material.

6.4.3 Application of Double Contingency Principle

Satisfying the double contingency principle requires that at least two unlikely, independent, and concurrent changes in process conditions would be necessary before a criticality accident is possible. No independent failures are identified that can lead to an inadvertent criticality.

6.5 Criticality Protection Program

The INEEL criticality safety program provides the requirements for retrieval, handling, and storage of fissionable material. This program is based on applicable standards in current contractual requirements and implemented by appropriate INEEL policies, standards, and procedures. The INEEL has implemented an approved nuclear criticality safety program in accordance with DOE Order 420.1A. The criticality safety program is followed for all project activities to ensure that fissile material is handled in such a way that a criticality accident is prevented and mitigated.

6.5.1 Criticality Safety Organization

The INEEL criticality safety program implements DOE Order 420.1A, which applies to fissile materials that pose a criticality accident hazard. The program implements controls for fissile materials that are produced, processed, stored, transferred, disposed, or otherwise handled to ensure that the probability of a criticality accident is acceptably low. The program ensures, to the extent practicable, that the public, workers, property (both government and private), the environment, and essential operations are protected from the effects of a criticality accident.

The nuclear operations facility management is responsible for establishing the criticality safety program. The criticality safety staff provides technical support for the criticality safety program. This includes documenting the requirements and recommendations of the criticality safety program and performing criticality safety evaluations and reviews to support facility safety analyses. Facility management is responsible for safe operations at facilities containing fissile material.

6.5.2 Criticality Safety Plans and Procedures

The criticality safety program has a wide array of safety plans and procedures currently in use throughout the INEEL. All operations and maintenance are governed by existing documentation, or additional plans and procedures are implemented. The procedures include all controls and limits specified in the criticality safety analysis. Procedures are supplemented with posted criticality safety limits, if required, and clearly designated evacuation routes.

6.5.3 Criticality Safety Training

The nuclear facility manager establishes a program for selecting, training, and testing individuals and their hnctional supervisors who handle fissionable material. Training emphasizes that workers must understand and follow applicable safety procedure requirements. All workers handling significant quantities of fissile material (greater than 15 FGE) within nuclear facilities are trained in accordance with the criticality safety training program requirements.

6.5.4 Determination of Operational Nuclear Criticality Limits

Operational nuclear criticality limits are established based on the criticality safety principles and criteria, accepted handbook data, criticality safety calculations or evaluations, and criticality safety analyses. Operational nuclear criticality limits are implemented as Technical Safety Requirements.

6.5.5 Criticality Safety Inspections and Audits

Criticality safety inspections and audits are conducted in accordance with the program.

6.5.6 Criticality Infraction Reporting and Follow-Up

Noncompliance with a criticality safety control is defined as any deviation from safety procedures that may affect the criticality safety or any activity involving fissionable materials. Reporting and follow-up criticality infractions are reported and documented in accordance with current INEEL procedures and manuals and DOE Order 232.1A.[13]

6.6 Criticality Instrumentation

In accordance with DOE Order 420.1A, neither a criticality alarm system nor a criticality detection system is required in facilities where the probability of a criticality accident is determined to be beyond extremely unlikely. DOE Order 420.1A states "reasonable ground for incredibility may be presented on the basis of commonly accepted engineering judgment." Based on the criticality safety analysis in Section 6.3, the probability of a criticality accident underground or in the ISTD well header piping and off-gas treatment system is beyond extremely unlikely and, therefore, no criticality alarm system or criticality detection system is required for ISTD operations.

6.7 References

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2. DOE O 420.1A, 2002, "Facility Safety," **U.S.** Department of Energy, May 20, 2002

3. DOE-STD-3007-93, 1998, "Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities," Change 1, U.**S.** Department of Energy, September 1998

4. ANSI/ANS 8.1-1998, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," American National Standards Institute/American Nuclear Society, 1998

5. Peatross, R. G., 2003, *Radioactive Waste Management complex Safety Analysis Report Addendum J, The OU 7-10 Glovebox Excavator Method Project,* INEL-94-0226, SAR-4, Addendum J, Idaho National Engineering and Environmental Laboratory

6. ANS 1980, "*Plutonium Handbook: A Guide to the Technology,*" Vol. 1, 1980, Oz Wick, Ed., American Nuclear Society (ANS), La Grange Park, Illinois

7. Sentieri, P.J., 2003, "*Criticality Safety Evaluation for In Situ Vitrification Processing (ISV) at the Radioactive Waste Management Complex (RWMC) at INEEL,*" INEEL/EXT-03-00207, Idaho National Engineering and Environmental Laboratory, April 2003, Appendix B-6

8. LANL, 1996, Nuclear Criticality Safety Guide, LA-12808, Los Alamos National Laboratory, (LANL), Los Alamos, New Mexico

9. Clements, T. L., Jr., 1982 "Content Code Assessments for INEL Contact-Handled Stored Transuranic Wastes," WM-F1-82-021-C3. October, 1982, EG&G Idaho, Inc

10. Paxton, H. C., Pruvost, N. L., 1986 "*Critical Dimensions of Systems Containing 235U, 239Pu and 233U*", 1986 Revision, LA-10860-MS, Los Alamos National Laboratory, July 1987

11. CRC, 1982, "*CRC Handbook of Chemistry and Physics,*" 62nd Ed., Chemical Rubber Company

12. Sentieri, P.J., 2003, "*Criticality Safety Evaluation for In Situ Vitrification Processing (ISV) at the Radioactive Waste Management Complex at INEEL,*" INEEL/EXT-03-00207, Idaho National Engineering and Environmental Laboratory, April 2003.

13. DOE O 232.1A, 1997, "Occurrence Reporting and Processing of Operations Information," **U.S.** Department of Energy, July 21, 1997

7. RADIATION PROTECTION

Chapter 7 of SAR-100' contains generic information for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory and is applicable to this project. The following paragraph provides additional information specific to in situ thermal desorption.

The soil cover will contain radioactive materials beneath the surface and will shield direct radiation. Small quantities of radioactive materials may be brought to the surface during well emplacement. No radioactive materials are expected above ground except in the off-gas treatment system. Appropriate shielding and personal protective equipment will be provided as specified by the radiation protection program; thus, the radiation dose to operators is expected to be very low.

7.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

8. HAZARDOUS MATERIAL PROTECTION

Chapter **8** of SAR-100’ contains generic information for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory and is applicable to this project. The following paragraph provides additional information specific to in situ thermal desorption.

The soil cover will contain nonradioactive hazardous materials beneath the surface. Small quantities of hazardous materials may be brought to the surface during well emplacement. The off-gases in the well header piping and off-gas treatment system will also contain nonradioactive hazardous materials. The well header piping and off-gas treatment system will be operated at negative pressure and designed to contain these materials. All hazardous materials will be removed by the treatment system before the air is discharged to the environment. No nonradioactive hazardous materials are expected above ground except in the off-gas treatment system; thus, the exposure to operators is expected to be very low. The hazards associated with these materials have been evaluated in Chapter ***3*** of this document.

8.1 References

1. SAR-100, “INEEL Standardized Safety Analysis Report (SAR) Chapters,” Rev. 0, June 27, 2000.

9. RADIOACTIVE AND HAZARDOUS WASTE MANAGEMENT

9.1 Introduction

Small quantities of radioactive and nonradioactive hazardous waste will be generated by in situ thermal desorption (ISTD) operations. Only small quantities will be generated, because the ISTD process does not remove buried waste from the ground. Additional information is needed on wastes from the off-gas system. There will be high-efficiency particulate air filters and hydrocarbons from the carbon beds of the off-gas system that may have mixed TRU waste contamination. Some low-level, and possibly TRU, radioactive wastes and hazardous wastes will be generated as part of monitoring, maintenance, operations, and other routine ISTD activities. This chapter addresses how the ISTD-generated wastes will be managed through the Radioactive Waste Management Complex (RWMC) and Idaho National Engineering and Environmental Laboratory (INEEL) waste management program. The RWMC and INEEL waste management programs are also described in Chapter 9 of the RWMC Safety Analysis Report.

9.2 Requirements

The applicable codes, standards, and Department of Energy (DOE) orders from which the safety criteria described in this chapter were derived are listed as follows:

9.2.1 Federal Requirements

- DOE Order 231.1, Environment, Safety, and Health Reporting
- DOE Order 435.1, Radioactive Waste Management
- DOE M 435.1-1, Radioactive Waste Management Manual
- DOE Order 5400.1, General Environmental Protection Program
- DOE-ID 10333 (00), DOE-ID INEEL Interim Pollution Prevention Plan
- DOE-ID 10381, Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria
- 40 CFR, Parts 260 through 279 (as applicable), Protection of Environment
- 40 CFR 302.4, Designation of Hazardous Substances
- 49 CFR Parts 171 through 177 (as applicable), Transportation.

9.2.2 State and Local Requirements

- State of Idaho Statutes, Title 39, Health and Safety, Chapter 44, Hazardous Waste Management, Idaho Code Section 39-4401 through 39-4431, 2000.

9.3 Radioactive and Hazardous Waste Management Program and Organization

Waste management planning for the ISTD project will be developed if the project moves forward. Because ISTD only produces secondary wastes, waste disposition should fit within current INEEL disposal practices, except possibly for small quantities of TRU waste that may be generated.

INEEL Manual 17, Waste Management, contains the controlling documents for the INEEL waste management program. All facilities and activities that generate a radioactive or hazardous waste stream must follow the requirements in this manual. The program includes an aggressive waste minimization and recycling program to reduce the quantities of waste generated.

At INEEL, the waste management program is managed by the Waste Generator Services (WGS) organization. The WGS works with RWMC personnel to ensure that all waste is properly identified, characterized, packaged, handled, stored, and disposed of. In addition, WGS is responsible for defining and maintaining the program documents in Manual 17. The Integrated Waste Tracking System (IWTS) is a network application that assists personnel in tracking the creation, transportation, and disposal of hazardous, mixed low-level, and low-level waste.

A WGS facility representative is located at the RWMC and is supported by WGS specialists assigned to each specific waste stream. While RWMC has the ultimate responsibility for the wastes it generates, WGS personnel support characterizing the waste and planning for its disposition. The WGS representative performs the following hnctions.

- Pregeneration planning to prevent the generation of waste without appropriate controls
- Ensuring that waste-related hazards have been identified, their potential impacts analyzed and appropriate controls are in place
- Completing waste determination and disposition forms that document the life-cycle management of the waste, including process knowledge evaluation; additional waste determination, characterization, and verification; and selection of receiving facilities
- Coordinating with onsite or offsite receiving facility organizations for storage and treatment
- Making provisions for waste packages
- Certifying waste to waste acceptance criteria prior to transport in accordance with DOE Order 435.1
- Transporting waste in a consistent and compliant manner across the INEEL
- Completing final waste disposition, except for TRU waste.

As the responsible organization, RWMC must comply with all applicable requirements for regulated wastes per State and Federal regulations, DOE orders, company procedures, and the INEEL WAC.[1]

9.4 Radioactive and Hazardous Waste Streams or Sources

Because the radioactive and hazardous waste remains in the ground and under the soil cover during treatment, ISTD should not produce large quantities of waste as part of the process. Small quantities of secondary low-level and transuranic radioactive wastes, hazardous wastes, and mixed wastes may be generated during operations, monitoring, maintenance, and other routine ISTD activities. An accident releasing radioactive material or hazardous material could increase waste-contaminated material generated during cleanup.

9.4.1 Waste Management Process

Because the project activities will be conducted under an OU 7-13/14 Record of Decision (ROD), prepared pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), all of the waste streams will be considered CERCLA waste. Even if the work is performed as a non-time-critical removal action, wastes will still be managed as CERCLA waste. While onsite, the waste is managed in accordance with the substantive requirements of the applicable or relevant and appropriate requirements (ARARs). Administrative requirements such as Resource Conservation and Recovery Act (RCRA) timeframes or reporting requirements do not apply to the waste while remaining in CERCLA storage, but may be implemented if required by internal INEEL procedures, or may be adopted as best-management practices. Generally, where CERCLA waste is shipped offsite to a treatment, storage, or disposal facility (TSDF), the waste must comply with all applicable regulatory requirements (administrative and substantive), including compliance with the CERCLA off-Site rule (40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions").'

9.4.2 Waste Sources and Characteristics

9.4.2.1 Radioactive Waste

Low-level Waste

Radioactive waste may include contaminated soil, wipes used for radioactive contamination surveys, personnel protective equipment, decontamination wastes, and HEPA filters. Other low-level waste (LLW) may include gloves, booties, respirator cartridges, and other PPE. Average annual LLW generation from 1998 through 2002 at RWMC has been 56 cubic meters. In situ thermal desorption should not add significantly to this amount.

Transuranic Waste

Some of the subsurface areas considered for ISTD treatment contain buried TRU waste Transuranic radionuclides may be brought to the surface, creating TRU waste.

9.4.2.2 Sources of Hazardous Waste. Potential hazardous wastes are items contaminated with the hazardous materials buried in the SDA and being treated by ISTD. Emplacement of the wells and operating of the off-gas system are particularly susceptible to generating hazardous waste. Average annual hazardous waste generation from 1998 through 2002 was 71 cubic meters. In situ thermal desorption should not significantly increase this amount unless there is an accident.

9.4.2.3 Sources of Mixed Waste. Since ISTD is treating both radioactive and hazardous buried waste, there is a potential for the radioactive and hazardous wastes discussed above to become mixed waste.

9.4.3 Waste Handling or Treatment Systems

9.4.3.1 Radioactive Waste

Low-level Waste

Most LLW is disposed of at RWMC without treatment; however, LLW may be sent offsite for treatment and/or disposal. All LLW offered for commercial treatment and/or disposal by RWMC is characterized and certified to meet the waste acceptance criteria (WAC) at the commercial treatment and/or disposal facility.

Transuranic Waste

No TRU waste is currently generated at RWMC as a result of facility operations; however, plans are being developed to dispose of TRU generated by the Glovebox Excavator Method Project. These plans include storing at the INEEL in a RCRA-permitted storage area, processing through the Advanced Mixed Waste Treatment facility, and shipping to the Waste Isolation Pilot Plant. A similar approach could be implemented for ISTD-related TRU waste.

9.4.3.2 Hazardous Waste. Treatment of hazardous waste generated at RWMC can be conducted either at RWMC (generator treatment) or at a permitted Treatment, Storage, and Disposal Facility (TSDF). Treatment at a permitted TSDF is used most often. Hazardous waste is packaged per the WAC for the offsite TSDF and applicable regulations. Waste Operations personnel arrange for transportation to the permitted TSDF.

9.4.3.3 Mixed Waste. Mixed waste is placed in RCRA-approved temporary storage areas and then collected and shipped offsite to licensed disposal facilities.

9.4.4 Normal Emissions

The off-gas treatment system will produce emissions during ISTD processing. Further work is needed to determine permitting requirements.

9.5 References

1. DOE/ID-01-10381, Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria (RRWAC), Rev 16, December 2002

2. 40 CFR 300.440, “Procedures for Planning and Implementing Off-Site Response Actions,” *Code of Federal Regulations*, Office of the Federal Register, October 2002.

10. INITIAL TESTING, INSERVICE SURVEILLANCE, AND MAINTENANCE

Chapter 10 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory. This information is applicable to in situ thermal desorption (ISTD).

It is planned to conduct a test program for the ISTD concept in a nonhazardous environment before the system is deployed at RWMC. Details of this test program are under development. Results from the test program will be factored into the final system design and Documented Safety Analysis.

The effectiveness of the off-gas treatment system, including effluent monitoring and standby diesel generator; and soil pressure monitors, which are safety significant SSCs, will also be tested after the system is installed at the RWMC and before ISTD operations begin.

10.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000

11. OPERATIONAL SAFETY

Chapter 11 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory. The following information is specific to in situ thermal desorption (ISTD).

11.1 Fire Protection

A Fire Hazard Analysis will be performed before ISTD is implemented at Radioactive Waste Management Complex. There are several potential fire safety concerns involved in ISTD. These include the following:

- Propane tank
- Propane burner in the off-gas system thermal oxidizer
- Combustible materials in the waste
- Combustible off-gases
- Diesel fuel for the diesel generator.

The Fire Hazard Analysis will address these concerns and appropriate controls will be implemented.

11.2 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

12. PROCEDURES AND TRAINING

Chapter 12 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory. The information in Chapter 12 of the Idaho National Engineering and Environmental Laboratory Safety Analysis Report is applicable to in situ thermal desorption.

12.1 References

1. SAR-100, “INEEL Standardized Safety Analysis Report (SAR) Chapters,” Rev. 0, June 27, 2000.

13. HUMAN FACTORS

Chapter 13 of SAR-100' contains generic information for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory and is applicable to this project. The following paragraph provides additional information specific to in situ thermal desorption (ISTD).

The purpose of this chapter is to address the human-machine interface associated with safety SSCs. The safety-significant systems for ISTD are the off-gas treatment system, including effluent monitoring and standby diesel generator; and soil pressure monitors. These systems require routine surveillance and maintenance, but do not involve regular human interaction and control during ISTD treatment. At this time, the design of these systems is not sufficiently developed to assess human factors. This information will be developed as the design progresses.

13.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

14. QUALITY ASSURANCE

Chapter 14 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory (INEEL). The information in Chapter 14 of the INEEL Safety Analysis Report is applicable to in situ thermal desorption.

Quality Assurance controls will be required for the design, procurement, fabrication, and installation of the safety-significant off-gas treatment system, including the induced draft fans and the stack monitoring system; the standby diesel generator; and the soil pressure monitors. These will be managed in accordance with the INEEL Quality Program.

14.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

15. EMERGENCY PREPAREDNESS PROGRAM

Chapter 15 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory. The information in Chapter 15 of the Idaho National Engineering and Environmental Laboratory Safety Analysis Report is applicable to in situ thermal desorption.

15.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

16. PROVISIONS FOR DECONTAMINATION AND DECOMMISSIONING

Chapter 16 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory. The information in Chapter 16 of the Idaho National Engineering and Environmental Laboratory Safety Analysis Report is applicable to in situ thermal desorption (ISTD).

Decontamination and decommissioning of ISTD is expected to include disconnecting and removing the off-gas treatment system and other processing trailers. The wells and well header piping will be grouted and left in place. A soil cover and cap will be placed over the ISTD treatment area. Grouting is being considered as a method for stabilizing the treatment areas to fill voids left by ISTD treatment and prevent subsidence.

16.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

17. MANAGEMENT, ORGANIZATION, AND INSTITUTIONAL SAFETY PROVISIONS

Chapter 17 of SAR-100' contains the information that is generic for all documented safety analyses prepared by the Idaho National Engineering and Environmental Laboratory and describes the site-wide management, organization, and institutional safety provisions, which are applicable to in situ thermal desorption. Specific management, organization, and institutional safety provisions pertaining to the Radioactive Waste Management Complex are described in this chapter of the main body of the Radioactive Waste Management Complex Safety Analysis Report. This information is applicable to the project. Details on management for implementation of ISTD will be developed in the future and included in the documented safety analysis.

17.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.